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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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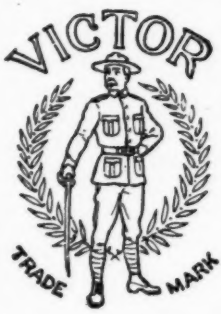

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VOL. I. MAY-JUNE, 1907. No. 3.

SOME COSMICAL ASPECTS OF RADIOACTIVITY.

BY E. RUTHERFORD.

THE subject of my address this evening quite naturally divides itself into two parts, one dealing with the properties of the radioactive bodies themselves and the other with the distribution of radioactive matter throughout the surface of the earth, and throughout the volume of our atmosphere.

It is the latter division of the subject that I wish more particularly to discuss this evening, but before doing so, it may be advisable to mention briefly some of the more important properties of the radioactive bodies themselves, so that we may be able to judge of the methods employed to detect and measure the minute quantities of radioactive matter scattered throughout the earth and atmosphere.

I shall not speak here of the early history of Radioactivity, which is no doubt well known to most of my audience. As a result of a large amount of detailed investigation, a considerable number of distinct radioactive substances have been isolated. Among the best known of these are uranium, thorium, actinium, radium and polonium, and the numerous substances which arise from their transformation.

Of all the substances separated from uranium or thorium minerals, radium has occupied the most important position. This is partly due to the comparative ease with which it can be chemically isolated and purified, but mainly to its great activity or radiating power, which is about two million times as intense as that of uranium.

The distinguishing feature of radioactive bodies in general, is their power of spontaneously and continuously emitting special types of radiation, of giving out heat, and also in some cases of giving out light. These properties in the case of radioactive substances like uranium and thorium, continue, if not indefinitely, at any rate for periods of time measured by millions of years. In the case of radium, the duration of the activity is shorter, but is still measured by thousands of years. This emission of radiations is spontaneous and is completely independent of control, whether by physical or chemical agencies.

I shall take radium as an example of a typical radioelement, but it must be borne in mind that most of the other active substances possess similar radioactive properties. Radium emits three types of rays, called the α, β and γ rays. The α rays are distinguished by their slight power of penetration of matter. A thin sheet of notepaper suffices to cut off the α radiation completely. These rays have been shown to consist of heavy atoms of matter carrying a positive charge of electricity, expelled from the active substances at a speed of about 20,000 miles per second. It seems probable that the α particle consists either of a charged hydrogen or helium atom, and most probably the latter.

The β rays are more penetrating than the α rays and carry a negative charge of electricity and are projected from the active substance at a speed much greater than that of the α particle. Some of the β particles from radium escape with a speed nearly equal to that of light, or 186,000 miles per second. Their apparent mass is only about one thousandth of that of the α particle, and in fact they are identical with the electrons produced in the cathode ray discharge of a vacuum tube.

The γ rays possess extraordinary penetrating power, passing readily through several inches of iron. It is now fairly certain that the γ rays are ethereal waves similar in character to the well known Röntgen rays, only of a more penetrating kind.

All of these types of radiation possess in common the properties of acting on a photographic plate and of producing phosphorescence in a certain class of substances, but from the point of view of measurement, their most important property is their power of causing the discharge of electricity from electrified bodies. This property is by far the most delicate test of radioactive matter and we shall consequently consider it in some detail. If we take an ordinary well-insulated gold-leaf electroscope and charge it so that the gold leaves diverge widely, it is well known that under ordinary conditions with good insulation, the leaves collapse extremely slowly, and over a few minutes' interval the leaves will appear to be almost stationary. Now bring some radioactive matter near the exposed plate of the electroscope. The leaves at once commence to collapse rapidly. This is due to the loss of charge from the electrified system, and takes place with equal rapidity whether the charge is positive or negative. The mechanism by which this discharge is produced has been most carefully studied, and it is known that the effect is due to the property possessed by these radiations of making the volume of the air surrounding the electroscope, a partial conductor of electricity. The radiations in passing through a gas produce a number of positively and negatively charged carriers or "ions." These ions move in an electric field. If, for example, the electroscope is charged positively, the negative ions are drawn towards the charged system. The discharging effect is thus due to the drawing in of a great number of negatively charged ions to the positively charged conductor or vice versa. The moment the radioactive substance is removed, the rapid movement of the leaves at once ceases.

This property of the radiations of ionizing the air or other gas is an extraordinarily delicate test of the presence of radioactive matter. I bring up near the electroscope a watch glass

on which has been evaporated a solution, containing only one millionth of a gram of radium bromide. The leaves collapse in a few seconds. If I place the watch glass on the plate attached to the electroscope, a charge given to the electroscope is almost instantly dissipated. The discharging effect in this case is due mostly to the α rays. This can be shown by placing a sheet of ordinary paper, which absorbs the α rays, over the watch glass —the rate of collapse of the leaves becomes now much slower. The residual discharging effect is then due to the β and γ rays from the small quantity of radium.

From the point of view of measurement, a millionth of a gram of radium produces far too large an effect. In practice, it is found that a quantity of radium measured by one thousand millionth (10^{-9}) of a gram produces an effect of magnitude suitable for accurate measurement. With care, in a suitably designed electroscope, it is possible to measure the presence of one hundredth of this latter amount and in some cases of one thousandth. The electroscope is thus capable of detecting by its increased rate of discharge a quantity of radium measuring 10^{-12} of a gram. As an agent for detecting minutest quantities of radioactive matter, the electroscope is far more sensitive than the spectroscope.

Such measurements do not of themselves throw any light upon the type of radioactive matter which produces the discharge. It would be difficult, for example, to be sure whether the radioactive matter present was radium, actinium or thorium. But there is another property of these substances which allows us to distinguish readily between them. Each of the substances, radium, thorium and actinium gives off steadily a radioactive "emanation" or gas which has very intense radioactive properties. If a current of air, for example, is passed over a thorium or actinium compound and then carried into an electroscope, a rapid collapse of the leaves is observed. This is due to the radiation from the emanation, which produces a large number of ions in the air with which it is mixed. In the case of radium, the emanation does not escape from a solid com-

pound but is readily released by heat or by solution. I have here a solution of radium in a closed bottle. The emanation has collected in the air space above the solution, and on passing a slow stream of air through the solution into the electroscope, some of this emanation is carried with it, and as you see, causes an extremely rapid discharge of the electroscope. If the emanation were left in the electroscope, it would preserve its discharging power for several weeks. The discharging effect would not be constant but would decrease to half value in four days, to one quarter value in eight days, and so on : and would still be appreciable after a month's interval. In fact, the radium emanation is an unstable substance which breaks up with the emission of α particles. On an average, half of it breaks up in four days. The emanations of thorium and actinium are chemically quite distinct from that of radium and can be at once distinguished from it by the rapid rate at which their activity dies away with time. The emanation of thorium falls to half value in 54 seconds and that of actinium in 3·9 seconds.

The production of the radioactive emanation by radium offers an extremely simple and reliable method of determining not only whether radium is present, but also of measuring accurately the quantity present. Suppose, for example, that we wish to determine the amount of radium present in a given specimen of rock. This is dissolved and placed in an air-tight vessel and left for about one month. During this time the emanation collects in the solution and the air space above it, and reaches a steady equilibrium value where the rate of production of new emanation compensates for the disappearance of emanation due to its further transformation. The solution is then boiled, and the air mixed with emanation is passed into a suitable electroscope and the rate of movement of the gold leaves noted.

If the rate of discharge decreases to half its initial value after about four days, it is certain evidence that the radium emanation is present in the electroscope. The amount of radium

in the rock is determined by treating in a similar manner a solution containing a *known* quantity of radium and observing the rate of discharge of the electroscope, produced by the emanation from it. By this method, we are not only able to detect the presence of radium in a substance, but also to determine the amount present with considerable accuracy. In this way, a quantity of radium in a solution of only 10^{-11} gram can be readily measured.

The emanation from radium is an unstable substance and breaks up into another substance which behaves as a solid and has quite distinct radioactive properties. The inside surface of a vessel containing the radium emanation becomes coated with an invisible deposit of radioactive matter. If the emanation is rapidly blown out by a current of air, this "active deposit," as it is called, remains behind. The activity of this deposit is not permanent but decays rapidly with the time. After several hours, the activity decreases in a geometrical progression falling to half value in about 28 minutes. For thorium, the active deposit loses half of its activity in 11 hours, for actinium in 34 minutes. The production of this characteristic active deposit from each emanation offers another very useful method of distinguishing whether thorium, radium or actinium is present.

An interesting property of the active deposit, which we shall see has played a notable part in the analysis of the radioactive state of the atmosphere, is its concentration on a negatively charged conductor in an electric field. The carriers of the active deposit become in some way positively charged and are drawn in to the negative electrode and adhere to it.

RADIOACTIVE STATE OF THE ATMOSPHERE.

I have now passed rapidly over some of the more important properties of radioactive bodies, which have proved of great utility in the attack on the question of the distribution of radioactive matter in the earth and atmosphere. The pioneers in this work were Professors Elster and Geitel, teachers in the Gymnasium of Wolfen-büttel, Germany, and to these investigators we

owe a large amount of the information now collected in this important and rapidly growing branch of radioactivity.

Geitel had observed in 1900 that the open air possessed the property of causing a slow discharge of an electroscope, and showed that this effect was due to the production of positive and negative ions in the air. In seeking for a possible cause of this effect, it occurred to Elster and Geitel that it might be due to the presence of some radioactive matter in the atmosphere. They then tried an extremely bold experiment. I have shown you that the emanations from the radioactive bodies produce an active deposit, which can be concentrated on a negatively charged wire. If any radioactive emanation were present in the

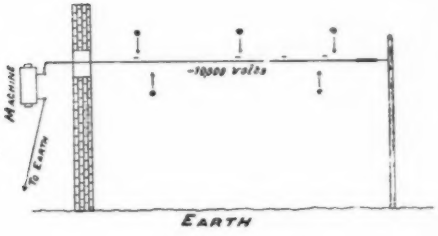


FIG. 1.

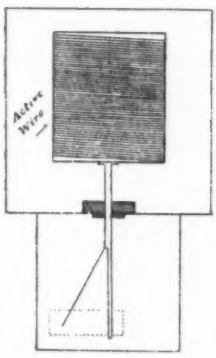


FIG. 2.

atmosphere, the active deposit should collect on a negatively charged wire exposed in it. An insulated wire 20 or 30 metres long (Fig. 1) was strung outside a laboratory window and kept charged negatively to a potential of several thousand volts by means of a battery or electrical machine. After several hours, the wire was rapidly removed, coiled round a frame attached to the electroscope, similar to that shown in Fig. 2, and the rate of discharge of the electroscope observed. The gold leaf was found to collapse rapidly, indicating that some radioactive matter was present upon the wire. The magnitude of this effect was inde-

pendent of the material of the wire and was conclusively shown to be due entirely to the presence of radioactive matter on its surface.

We must next consider how to determine the *kind* of radioactive matter concentrated upon the wire. In the first place, it is improbable that particles of the solid radioactive bodies like radium, uranium or thorium should be present in the atmosphere. But the emanations from radium, thorium and actinium are gaseous, and if the earth contains these substances, we might reasonably expect that some of the emanation released from them might escape into the atmosphere. We have at once a means of definitely settling this question. If the radium emanation alone is present in the atmosphere, the active deposit collected on the wire should decay at the rate characteristic of radium, *i.e.*, after some hours, the activity should decay exponentially decreasing to half value every 28 minutes. The rate of decay of the active deposit from the air has been shown to be very similar to this, so we conclude that the radium emanation is present in the atmosphere.

The experiment of Elster and Geitel in Germany was repeated by Rutherford and Allan in Montreal and by Professor McLennan in Toronto and the results showed that the air of Canada is as radioactive as that of Germany. Falling rain, or snow is also radioactive, and its activity decays at the characteristic rate to be expected if the falling rain or snow collects upon it the active deposit of radium distributed throughout the atmosphere.

Preliminary experiments showed that most of the radioactive effect of the atmosphere was due to the presence of the radium emanation. Bumstead, in New Haven, and Blanc, in Italy, have however clearly shown that in these localities some thorium emanation is also present. This can be tested in a very simple way. A wire is made active by exposure as negative electrode to the open air for several days. On removal, part of the activity due to the active deposit of radium decays rapidly. After 5 or 6 hours, an activity still remains which decays much

more slowly, decreasing to half of its value every 11 hours. This is the rate of decay characteristic of the active deposit of thorium and shows that the thorium emanation must also be present in the atmosphere. In some parts of Italy, Blanc has recently shown that fully 70 per cent. of the activity on the wire must be ascribed to thorium, but apparently the effect due to radium predominates in most other localities.

We may consequently conclude that the atmosphere over the surface of the earth contains everywhere small quantities of the radium and thorium emanation and also the active substances arising from their transformations *in situ* in the atmosphere. The amount of ionization thus produced is small, but can be accurately measured by apparatus specially designed by Ebert for the purpose. By means of a fan driven by a spring motor, a steady current of air is drawn between two concentric cylinders. The inner insulated cylinder is charged and connected with an electroscope. As the ionized air passes between the cylinders, the ions are removed by the strong electric field between them. The rate of discharge of the electroscope serves as a measure of the number of ions per cubic centimetre of the volume of outside air. In the open air, there are usually about 1,500 ions per c.c. of the air; the number is not constant but fluctuates considerably. This number of ions present in the atmosphere is extraordinarily small compared with the number of un-ionized molecules. Each cubic centimetre of air contains about 4×10^{19} molecules, so that on an average only an infinitesimal proportion of the molecules are ionized at one time. While this ionization appears very insignificant, needing a delicate electroscope to detect and measure it, yet it has a very important bearing on the electrical state of the atmosphere.

We must bear in mind that all of us are continuously inhaling the radium and thorium emanations and their products, and ionized air. In addition we are continuously undergoing a type of mild X-ray treatment, for the β and rays from the earth and atmosphere continuously pass into and through our bodies. We are in fact, subjected to a continuous bombardment

by the radiations from active matter and are fortunately quite unaware of it. Some have considered that possibly the presence of radioactive matter and ionized air in the atmosphere may play some part in physiological processes, but this is a question quite outside the scope of my address.

An examination of the electrical state of the atmosphere shows that the upper atmosphere is nearly always positively charged, so that the earth must be negatively electrified. There is consequently an electric field normal to the earth which causes a steady movement of the positive ions in the air towards the earth and a corresponding movement of negative ions upwards. The latter must tend to dissipate rapidly the positive electricity in the upper atmosphere.

There are many theories as to the origin and maintenance of the positive charge in the upper atmosphere. One very plausible hypothesis, supposes that the electrical state of the atmosphere largely results from the radioactive matter distributed throughout it. The appearance of positive electricity in the upper atmosphere is in this view due to the effect of falling rain carrying the negative charge to earth ; for it is found that rain is always negatively electrified. The presence of an ionized layer of gas between the upper atmosphere and the earth tends continually to dissipate the positive charge left behind, and this ordinarily prevents the increase of positive electricity to the danger limit, when lightning discharges would pass to the earth. It thus appears probable that the insignificant amount of radioactive matter in the atmosphere plays an important rôle in causing and controlling the electrical state of the atmosphere.

AMOUNT OF RADIUM EMANATION IN THE ATMOSPHERE.

The amount of radium emanation in the air per cubic centimetre of its volume is extremely small but can be measured by several methods. This problem has been attacked by A. S. Eve of Montreal, who found that a cubic kilometre of the atmosphere contains an amount of emanation equivalent to that liberated from about half a gram of radium bromide in radioactive equi-

librium. Assuming that the amount of emanation in the air over the land surface of the globe is about the same as in the neighbourhood of Montreal, and that on an average, this distribution is uniform over a height of ten kilometres of the atmosphere, he concluded that the total amount of radium emanation in the atmosphere was equal to that liberated from about 200 tons of radium bromide in equilibrium. It is probable that the amount of radium emanation over the sea is less than that over the land, and is mainly conveyed there by winds from the land, but there is still some uncertainty on that important question.

As I mentioned before, it is extremely improbable that much solid radium in the form of fine particles exists in the air, so that for the supply of emanation to the atmosphere we must look to some external source. We shall now discuss the evidence which leads us to believe that the supply of emanation to the atmosphere is kept up by its steady escape from the surface crust of the earth.

DISTRIBUTION OF RADIOACTIVE MATTER IN THE EARTH'S CRUST.

Elster and Geitel early observed that many caves and cellars, in which the air had been confined for long intervals of time, was unusually rich in the radium emanation. This was shown by the strong activity observed on negatively charged wires exposed in these confined places. Such a result is to be expected if the radium emanation continuously escapes from the soil, for the amount of it present must increase in such confined spaces. This led them to make an examination of the activity of soils. All were found to be active and many gave off the radium emanation. This effect was especially marked in clayey soils. J. J. Thomson and others showed that the water in many deep wells and springs was impregnated with the radium emanation. The presence of the radium emanation is especially marked in many of the hot springs distributed throughout Europe. Elster and Geitel

observed that the sediment from certain hot springs in Italy was unusually rich in radium. Blanc showed that the sediment from certain hot springs gave off freely the thorium emanation. A very great deal of work has been done along these lines in the last few years, and radioactive matter has been found to be very widely distributed, in small quantity, over the earth's crust. The continent of North America has not been so systematically examined as Europe, but Boltwood has shown that a large amount of radium emanation is present in the waters from many deep-seated springs in various localities in the United States. McLennan and Burton have shown that the petroleum from the oil wells in Ontario contains a considerable quantity of radium emanation and also a trace of radium.

There appears to be no reasonable doubt that the earth is the source of the emanation in the atmosphere. This emanation escapes from the soil by the process of diffusion, or is borne to the surface in spring water and is then distributed by the winds. On account of the rapidity of the transformation of the emanations of thorium and actinium compared with that of radium, it is to be expected that the radium emanation will predominate in the atmosphere, and it is a matter of some surprise that the thorium emanation is present in such a large amount as is observed in some localities. The emanation of radium must diffuse slowly through the earth, disappearing with time, and it is to be expected, that, apart from deep-seated springs, most of the emanation observed in the air must be derived from a thin skin of the earth's surface not more than a few feet deep.

INTERNAL HEAT OF THE EARTH.

It is thus natural to suppose that there is a very large quantity of radium and other radioactive matter distributed over the surface of the earth. This radioactive matter must be continuously supplying heat to the earth, and it is of great interest to examine the magnitude of this heating effect and its probable bearing on the question of the origin and duration of the earth's internal heat.

In addition to the various properties I have enumerated, radium also gives out heat continuously and uniformly at a rapid rate. A quantity of radium supplies enough heat to melt more than its weight of ice per hour. A pound of radium in the course of a year will emit as much heat as that resulting from the combustion of 100 pounds of good coal. This heat emission of radium and of all the radioactive bodies is in reality a secondary property, for it is a consequence of the bombardment of the active matter by the α particles expelled from its own mass. The β and γ rays produce only a small percentage of the total heating effect. This heating effect of radium must always be proportional to the quantity of radium present and must persist, however sparse may be the distribution of radium throughout the earth's crust. Consequently, there must be a continuous supply of heat to the earth due to the radium and other radioactive matter distributed throughout it. But the heating effect due to a given quantity of radium does not last indefinitely. The radium breaks up into other forms and after 20,000 years only a small fraction of the radium would remain. This difficulty, however, is not serious, for it is now definitely settled that radium is produced from uranium and it is found that in old minerals the amount of radium is always proportional to the amount of uranium.

Now uranium is transformed extremely slowly in comparison with radium, and probably a period of at least one thousand million years would be required before the uranium was half transformed. Consequently, the supply of radium from the breaking up of uranium will keep up the amount of radium in the earth to a nearly constant value for periods measured by hundreds of millions of years.

We shall now consider briefly the ordinarily accepted theory of the origin of the earth's internal heat and of the age of the earth. It is known that the temperature of the earth steadily rises as we proceed from the surface inwards, and on an average rises 1° Fahr. for every fifty feet of descent. From the evidence

of volcanic action, it is concluded that the interior of the earth is at a high temperature.

Lord Kelvin attacked this question of the age of the earth by supposing that the earth was originally at a temperature of molten rock and has since that time gradually been cooling by the radiation of heat through the surface into space. According to this theory, the temperature gradient near the surface of the earth has been gradually decreasing. Knowing the temperature gradient to-day, and the average conductivity and specific heat of the materials of the earth, it is possible by the aid of Fourier's celebrated analysis to deduce the interval that has elapsed since the earth was a molten mass. Some of the values of the quantities necessary in the calculation are uncertain within limits, but Lord Kelvin concluded that certainly not more than 100 million years can have elapsed since the surface of the earth was at a temperature capable of supporting animal and vegetable life. In later papers this estimate has been still further reduced, and the age of the earth is put as low as forty million years. I cannot here enter into the intermittent controversy that has raged for nearly half a century between Lord Kelvin on the one hand and the geologists and biologists on the other. The latter initially required a much longer period for the progress of geologic and biologic evolution than that allowed by Kelvin, but there appears to be a general consensus of opinion among geologists and biologists to-day, that a period of 100 million years allows sufficient time for the processes of evolution.

On the assumptions made by Lord Kelvin, there is no doubt of the general accuracy of the deductions. Let us however examine these fundamental premises. The earth is assumed to be a cooling body isolated in space, and it is assumed that there has been no supply of heat to the earth since the cooling began ; for Kelvin has conclusively shown that the heat supplied from ordinary chemical processes, that may be supposed to occur in the earth, is not sufficient to influence materially the conclusion as to the age of the earth's heat. But the discovery of the presence in the earth of active matter like

radium which emits heat at a rapid rate, at once suggests the possibility that the earth is not a simple cooling body, but one in which heat is being steadily generated. In 1902, I made some calculations to determine how much radium (or other radioactive matter expressed in terms of radium) would be required to be uniformly distributed throughout the earth in order to maintain the present observed temperature gradient. In such a case, the heat supplied by the radium must exactly compensate for that lost from the earth by conduction to its surface and radiation into space. The calculations are simple, and show that a uniform distribution of radium amounting to only $1{\cdot}7 \times 10^{-13}$ gram of radium per cubic centimetre would suffice. From the data then available, I calculated that the amount of radium present in the earth was probably of the right order of magnitude to produce such a result.

Recently, the Hon. R. J. Strutt has made a number of systematic observations to determine the distribution of radium in the typical rocks of the earth's crust, and has obtained results of remarkable interest. Strutt collected a number of typical rocks, both igneous and sedimentary, obtained from widely different localities, and determined the amount of radium contained in them. The rocks were first of all obtained in solution and placed aside in closed vessels. After a definite time the emanation, generated by the radium contained in them, was boiled out, and passed into a suitable electroscope. The amount of radium in the solution was then determined by comparison with the effect in the electroscope due to the emanation from a standard solution containing a known quantity of radium bromide.

The following table shows the observed amount of radium in grams per cubic centimetre of rock for samples of igneous rocks.

No.	Name of rock	Locality	Density	Radium per gram in grams	Radium per c.c., in grams
1	Granite	Rhodesia	2·63	$9·56 \times 10^{-12}$	$25·2 \times 10^{-12}$
2	"	Lamorna Quarry, Cornwall	2·62	9·35 "	24·5 "
3	Zircon syenite	Brevig, Norway	2·74	9·30 "	25·5 "
4	Granite	Rosemorran, Cornwall (?)	2·62	8·43 "	22·1 "
5	"	Cape of Good Hope	2·67	7·15 "	19·1 "
6	"	Knill's Monument, near Carbis Bay, St. Ives, Cornwall	2·61	6·90 "	18·0 "
7	"	Shap Fell, Westmoreland	2·65	6·63 "	7·6 "
8	Elæolite syenite	Laurdal, Norway	2·70	4·88 "	3·2 "
9	Granite	Haytor, Devonshire	2·61	3·69 "	9·64 "
10	Blue ground	Kimberley	3·06	3·37 "	0·3 "
11	Leucite basanite	Mt. Somma, Vesuvius	2·72	3·33 "	9·07 "
12	Hornblende granite	Assouan, Egypt	2·64	2·45 "	6·47 "
13	Pitchstone	Isle of Eigg	2·41	2·06 "	4·97 "
14	Hornblende diorite	Schriesheim, near Heidelberg	2·89	1·98 "	5·73 "
15	Augite syenite	Laurvig, Norway	2·73	1·86 "	5·07 "
16	Peridotite	Isle of Rum	3·15	1·37 "	4·32 "
17	Olivine basalt	Talisker Bay, Skye	2·89	1·32 "	3·82 "
18	Olivine euchrite	Isle of Rum	2·97	1·28 "	3·80 "
19	Basalt	Victoria Falls	2·75	1·26 "	3·46 "
20	Hornblende granite	Mt. Sorrel, Leicestershire	2·71	1·25 "	3·38 "
21	Dolerite	Isle of Canna	2·95	1·24 "	3·65 "
22	Greenstone	Carrick Dû, St Ives	2·99	1·14 "	3·41 "
23	Basalt	Giants' Causeway, Antrim	2·80	1·03 "	2·89 "
24	Serpentine	Cadgwith, Lizard	2·60	1·00 "	2·60 "
25	Granite	Isle of Rum	2·61	0·723 "	1·89 "
26	Olivine rock	Isle of Rum	3·22	0·676 "	2·18 "
27	Dunite	L. Scaivig	3·34	0·664 "	2·22 "
28	Basalt	Ovifak, Disco Island, Greenland	3·01	0·613 "	1·84 "

I mentioned before that about $1·7 \times 10^{-13}$ gram of radium per c.c. distributed uniformly throughout the volume of the earth, would keep up the earth's internal heat. An examination of the above table, however, shows that the surface rocks contain far more radium than this. As we should expect, the radium content varies considerably, but the poorest rock of all, Greenland basalt, contains more than ten times this estimate,

while the average rock contains fifty or sixty times as much. An examination of the sedimentary rocks shows an average amount of radium somewhat smaller than that of the igneous rocks, but still of the same order of magnitude. Strutt considers that 5×10^{-12} gram of radium per c.c. is a fair average for the surface rocks of the earth—a quantity thirty times greater than that required to maintain the present temperature gradient. This is a surprising result, for although of necessity only a small number of rocks have been examined, yet we must consider that the results obtained by Strutt probably give the right order of magnitude for the distribution of radium in the earth's crust. It will be observed that very few rocks from the American continent figure on the above list. This omission will no doubt be soon rectified by other observers. It is of interest to note that Eve and MacIntosh of McGill University have recently examined the amount of radium in the typical rocks in the neighbourhood of Montreal, and have obtained an average value in substantial agreement with Strutt. By calculations based on the intensity of the penetrating or γ radiation at the earth's surface, Eve has deduced a value of the amount of radioactive matter in the earth's crust even greater than the average value found by Strutt. Not only therefore is the apparent amount of radium in the earth's crust sufficient to account for the maintenance of the earth's internal heat, but if uniformly distributed throughout its mass, there is far more than is required. The latter assumption would lead to the conclusion that the earth is growing hotter instead of colder—an explanation not likely to be regarded with favour. In order to get round this difficulty, Strutt suggests that the distribution of radioactive matter is not uniform throughout the earth, but is confined to a thin surface shell of the earth. Assuming the distribution of radium found by experiment to be uniform throughout this shell, it can readily be shown that its thickness is about 45 miles. In support of this explanation he cites the results of Milne, the seismologist, who concludes from an examination of the velocity of propagation of earth tremors through the earth, that there is a fairly abrupt

transition of the material of the earth's crust at a depth of 30 miles. Below this depth, the material appears to be uniform, and transmits earth tremors at quite a different rate from the surface rocks.

On the assumption that radium is confined to a shell 45 miles deep, it is easy to calculate the temperature of the earth as we proceed downwards. The results are shown in Fig. 3.

The temperature should rise to about 1,500° C. at a depth of 45 miles. The temperature of the interior mass of the earth below this depth must be uniform and equal to 1,500° C.

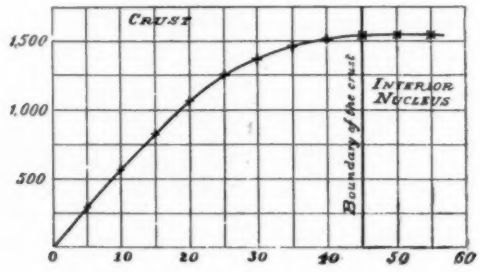


FIG. 3.

It is difficult at present to advance satisfactory reasons why this superficial distribution of radium should occur. Temperature can have little if any effect, for Bronson has conclusively shown that the radiating power of radium is not altered by exposure to a temperature of 1,600° C.

There is another interesting point raised by Strutt in regard to the internal temperature of the moon. The latter is supposed to have been initially separated from the earth's surface, and should thus contain the same average amount of radium as that found in the earth's crust. If this be the case, it can readily be deduced that the temperature gradient in the moon should be about eight times greater than in our earth. Taking into consideration that the force of gravity is small at the moon's surface, the conditions would appear to be very favourable for volcanic action in the moon. This is contrary to the general

opinion that the lunar craters are extinct, but as Strutt points out, this view rests chiefly on an *a priori* conviction that the moon has no internal heat. Professor W. H. Pickering has pointed out that close students of the moon believe that changes are still occurring there.

I hope that I have made clear to you how the study of radioactivity has profoundly altered our views of the earth's internal heat. The conclusions advanced are by no means completely proved, but sufficient has been done to cast grave doubt on the validity of the older theories of the origin and variation of the earth's internal heat.

AGE OF RADIOACTIVE MINERALS.

This new point of view of regarding the supply of the earth's heat does not throw any definite light on the problem of the age of the earth. This want, however, is supplied by taking into account still another very remarkable property of radium. In addition to its property of radiating and of emitting an emanation, radium also steadily produces from itself another stable element, helium. This property of radium was first shown by Ramsay and Soddy, and has been amply confirmed by other investigators. The weight of evidence at the present time points to the conclusion that the α particle, expelled from radium and its products, is in reality a helium atom, which at the moment of its expulsion carries a positive charge of electricity. Whatever may be the position of helium in the general scheme of radioactive transformations, there is no doubt that radium produces helium at a slow but constant rate. The rate of production of helium has not yet been measured with accuracy, but it is probable that one gram of radium will produce per year about one tenth of a cubic centimetre of helium at standard pressure and temperature.

This rare gas helium, which next to hydrogen, has the lightest atom known to chemists, has had an unusually dramatic history. It was first discovered in the sun by means of the

spectroscope by Lockyer in 1868, and hence its name. It was not found in the earth until 1895, when Ramsay showed that the gases liberated from the mineral cleveite, showed the spectrum previously attributed to helium in the sun. Now it is a very interesting fact that helium is only found in quantity in the radioactive minerals. The presence of helium in these minerals was at first considered very remarkable, but is at once explained if the helium is produced in the mineral by the radium or other radioactive matter contained in it. Consider, for example, a very dense radioactive mineral from which the helium continuously generated by the radium cannot escape. The amount of helium in the mineral will steadily increase with time, and the total amount present should be proportional to the age of the mineral and the amount of radium contained in it. I have here some crystals of a new mineral, thorianite, found a few years ago in Ceylon which contains about 12 per cent of uranium and about 70 per cent. of thorium. This mineral on heating evolves a remarkably large quantity of helium—more than 10 c.c. per gram of the mineral. Now it is almost certain that the helium stored up in this mineral has been produced by the breaking up of the radium, contained in it since the formation of the mineral. Assuming the rate of production of helium by radium already mentioned, it can be calculated with some confidence that the mineral thorianite is at least 500 million years old, *i.e.*, this interval of time must have elapsed since the formation of the mineral in the earth's crust. This is a minimum estimate, for probably some of the helium has in the course of ages escaped from the mineral. A similar result is obtained from consideration of other primary radioactive minerals. Most of them are apparently about 500 to 1,000 million years old.

When the constants involved in these calculations are accurately determined, I feel great confidence that this method will prove of the utmost value in determining with accuracy the age of the radioactive minerals and indirectly of the geologic strata in which they are found.

CONCLUSION.

I have so far confined my attention to the earth and her satellite the moon. Is there any evidence of the presence of radium or other radioactive matter in the sun or in the stars? We may say at once that no definite evidence has yet been observed. From the similarity of the chemical constitution of the sun with our earth, we should expect the sun to contain radioactive matter also. The large amount of helium observed in the sun indirectly supports such a conclusion. Strutt found that stony meteors contained about as much radium as the surface rocks of the earth, indicating that these visitors from other systems also have their share of radium.

There is no obvious reason for supposing that the sun, at any rate during the initial stages of its condensation, contained much more radioactive matter than the earth. According to the condensation hypothesis of Kelvin and Helmholtz, the heat of the sun is derived from the gradual concentration of its material due to gravitation. On this hypothesis, Kelvin considers it improbable that the sun will continue to shine at its present brilliancy for a period more than 12 million years and probably much less. There is one possibility, however, which may greatly extend the estimate of the duration of the sun's heat. At the enormous temperature of the sun, it is possible that ordinary matter may become radioactive, *i.e.*, it may break up into simpler forms, with the evolution of a great quantity of heat. If ordinary matter, in undergoing such change, emitted as much heat as radium in its transformation, this new source of heat would allow the sun to shine for a much longer period than the older theory allows. This is only a speculation, but one that must be taken seriously into consideration in coming to a decision of the probable duration of the sun's heat, and consequently of the time for habitation of our globe.

THE ASTRONOMY OF THE BIBLE.*

By J. Edward Maybee.

THE time is not far past when to approach such a subject in the spirit of scientific enquiry was liable to expose the rash investigator to a good deal of obloquy ; and even now, though the results of scientific investigation are accepted by all modern theologians, there are, I doubt not, many still left who conscientiously believe that the Bible, in addition to being an unfailing well of religious truth, contains nothing at variance with the conclusions of modern science.

With a diffidence, I hope, becoming to such a subject, I wish to present some arguments showing how little reason we have to expect that there should be revealed to the Jewish patriarchs a true understanding of natural phenomena, their nature and their causes.

We may assume as a Natural law, the result, presumably, of a Divine ordinance, that nothing is revealed to man that he can find out for himself. By bitter experience the child has to discover for himself the effects of gravitation. Not the most anxious parent can save the little one from many a tumble ere the art of balance becomes practically automatic action.

It would appear that nothing of real worth is given to a man from without ; he must slowly and laboriously earn his experience and his effective knowledge. As with the education of the individual so with the race. The records show us that no scientific knowledge has come from without, all has been gained during centuries of application, by the brightest minds of all the ages. God has endowed us with the faculties necessary, and with the will for research ; and, mayhap, especially endowed with talents the great men who form the landmarks, the milestones, in the progress of knowledge.

* Many of the passages alluded to in this paper are interpreted in a different sense to that presented by the author, who is responsible for the views expressed in it.—Editor.

In view of this at present universal law, have we any reason to suspect that an exception was made in the case of the forefathers of the Jewish race?

If we found that the Jews had especial light in any branch of knowledge other than theology, we might have some reason to suppose they may have had a revelation in the domain of natural science. But we do not. Whatever branch of their knowledge we examine, we seldom, if ever, find it in advance of the general knowledge of the time.

It may be remarked further that if any scientific revelation were to be given to man, there were and are many branches of knowledge more immediately useful to him than the knowledge of how the earth was made and the nature of the universe, and of such useful revelation we find nothing. One writer has said, "The all-important thing in Genesis is that God is the Creator." That knowledge we might not achieve for ourselves, though as to the process we have learned much and may learn more.

Again, the proper appreciation of scientific truth requires a good fundamental education—requires a mind trained in the scientific spirit. We all know cases where a lack of general knowledge and proper training has made a man incapable of assimilating the facts of modern science. If that is often the case now-a-days in the full glare of the light of modern knowledge, what chance was there that the ancient Jews, living in the twilight of the world, could derive any benefit from a revelation of the true nature of the universe. To them it would be but foolishness. Indeed the grand and fundamentally correct theories of Pythagoras and Aristarchus seemed foolish to their own and many succeeding generations. It was much better to let man work upward from the childhood of myth and fable to the stalwart and still growing man of Modern Science. We should not be surprised then, if we cannot always find a complete agreement between the beliefs of the Jewish writers and the views of modern science.

In ascertaining the views of the Jews on natural phenomena we must always keep in mind that the Jewish writers were

neither scientific nor philosophic, but primitive and poetical ; consequently their descriptions of what they saw are strictly in accord with objective appearances or else bear all the marks of poetic license. This last must particularly be kept in mind, for it is not fair to take poetic exaggerations as intended for literal facts. Still it is possible, by comparing text with text, to arrive at a fairly accurate understanding of the Jewish conception of the Universe. It must not be supposed that entire unanimity is to be found among all the writers, for opinions occasionally differ, but the consensus of opinion favors the scheme outlined in this sketch.

Of the two accounts of the Creation given in Genesis, that contained in the first chapter is the only one we need particularly discuss, as it alone touches matters astronomical.

"In the beginning God created the heaven and the earth. And the earth was waste and void ; and darkness was upon the face of the deep ; and the Spirit of God moved upon the face of the waters*." (Gen. i., 1-2).

The writer, it appears to me, has no conception that our orderly world was at one time a molten mass or a cloud of fire—the view ordinarily held by scientific men. "And God said, Let there be light : and there was light . . . . . and God divided the light from the darkness. And God called the light Day, and the darkness he called Night." (i., 3-5). Light seems to be conceived of as something quite distinct from the celestial sources of light, a not unnatural assumption. Some such simple hypothesis would explain the illumination of objects shielded from the direct rays of the sun or moon, an effect puzzling enough to a primitive people. That the writer of Genesis was not alone in this belief is evidenced by Ps. lxxiv., 16, 17,

> "The day is thine, the night also is thine :
> Thou hast prepared the light and the sun."

and also Ecc. xii., 2, "Or ever the sun, and the light, and the

* In all quotations the text of the Revised Version will be followed.

moon, and the stars, be darkened, and the clouds return after the rain." In Egyptian cosmogony the God Thoth, the demiurge, is said to have given the world light when all was darkness and there was no sun. Thus at this time it was conceived that during the day a diffused light illuminated a waste of empty waters which at night were wrapped in Plutonian darkness.

"And God said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters." This firmament seems to have been conceived as a huge transparent dome, supported on the borders of the earth. Compare Job xxvi., 11.

> "The pillars of heaven tremble
> And are astonished at his rebuke."

Also Amos ix., 6, "It is he that buildeth his chambers in the heaven, and hath founded his vault upon the earth." The brightness and strength of this vault are often referred to. Job xxxvii., 18, says,

> "Canst thou with him spread out the sky,
> Which is strong as a molten mirror."

In Daniel xii., 3, we find, "And they that be wise shall shine as the brightness of the firmament." In the splendid vision of Ezekiel i., 22, 26, we have a vivid word-picture painted with poetic fervor, "And over the head of the living creature there was the likeness of a firmament, like the color of the great and terrible crystal, stretched forth over their heads above . . . . . and above the firmament that was over their heads was the likeness of a throne, as the appearance of a sapphire stone." Here is a splendid suggestion of the luminous transparency of the firmament, permitting the light of the Sun and Moon and stars to shine through.

Above the firmament, part of the waters were gathered together in the storehouses of the rain. The view expressed in Genesis is borne out by Ps. civ., 13,

> "He watereth the mountains from his chambers."

and Ps. cxlviii., 4,

> "Praise him, ye heaven of heavens,
> And ye waters that be above the heavens."

The majority of the biblical writers conceived that through doors or windows in the firmament the rain was let down to refresh the earth. Such references are numerous, but one will suffice, Gen. vii., 7, "On the same day were all the fountains of the great deep broken up, and the windows of heaven were opened." Here also is another curious conception. "The fountains of the great deep" [or the abyss], are "the water under the earth" of the second commandment; and from these abysmal fountains arise the springs and rivers, while the seas are also connected with them. Compare Ps. xxxiii., 7,

> "He gathereth the waters of the sea together as an heap:
> He layeth up the deeps in storehouses."

And Job xxxviii., 16,

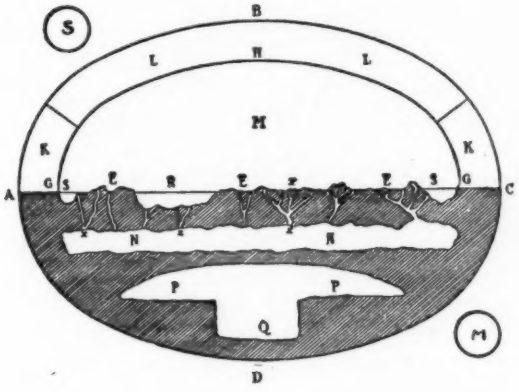
> "Hast thou entered into the springs of the sea?
> Or hast thou walked in the recesses of the deep?"

Also in Prov. viii., 24-30, we find a very complete cosmography. Here it is said of Wisdom,—

> "When there were no depths I was brought forth;
> When there were no fountains abounding with water."
>
> Before the mountains were settled,
> Before the hills, was I brought forth:
> While as yet he had not made the earth, nor the fields,
> Nor the beginning of the dust of the world.
>
> When he established the heavens I was there:
> When he set a circle upon the face of the deep:
> When he made firm the skies above:
> When the fountains of the deep became strong:
>
> When he gave to the sea its bound,
> That the waters should not transgress his commandment:
> When he marked out the foundations of the earth:
> Then I was with him."

In the accompanying diagram* is given a recent writer's view of the early Jewish conception of the Universe.

* Taken by permission from "Astronomy in the Old Testament" by G. Schiaparelli. Oxford, Clarendon Press, 1905.



G H G, the firmament or lower heaven; A B C, the upper heaven; A E C, horizontal plane of the earth and seas; S R S, various parts of the sea; E E E, various parts of the earth; K K, storehouses of the winds; L L, storehouses of the upper waters, of snow and of hail; M, the space occupied by the air; N N, the waters of the great abyss; *x x x*, the fountains of the great abyss; P P, sheol; Q, the pit.

Sheol, the "grave" or "hell" of the Authorised Version is conceived as a gloomy underworld receptacle for all alike, both just and unjust. Let me quote a few out of many passages referring to it.

> "For now should I have lien down and been quiet;
> I should have slept; then had I been at rest:
> With kings and counsellors of the earth,
> Which built up waste places for themselves;
> Or with princes that had gold,
> Who filled their houses with silver:
> . . . . . .
> There the wicked cease from troubling;
> And there the weary be at rest.
> There the prisoners are at ease together;
> They hear not the voice of the taskmaster,
> The small and great are there;
> And the servant is free from his master."
>
> Job iii., 13-19.

> "But those that seek my soul, to destroy it,
> Shall go into the lower parts of the earth."
>
> Ps. lxiii., 9.

"It is high as heaven; what canst thou do?
Deeper than Sheol; what canst thou know?"

Job xi., 8.

Speaking of the uncircumcised, Ezekiel xxxii, 23, says, "Whose graves are set in the uttermost parts of the pit"; and Isaiah xiv., 15, says of the King of Babylon, "Yet thou shalt be brought down to hell, to the uttermost parts of the pit." "Though they dig into hell, thence shall mine hand take them; and though they climb up to heaven, thence will I bring them down." (Amos ix., 2).

Round this symmetrical universe the Sun was supposed to move in an ordered course. Note for example Ecc. i., 5, "The sun also ariseth, and the sun goeth down, and hasteth to his place where he ariseth." The heaven of the stars appears to have been placed by the Jewish writers outside the course of the Sun and Moon,—naturally enough for its apparent motion differed from theirs. In contrast to the rigidity of the firmament the stellar heavens are spoken of as flexible in their nature, but as the passages in which such references occur are of a decidedly poetical nature it is not safe to impose on them a literal interpretation. Consider, *e.g.*, "He . . . . stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in" Psl. civ., 2; and also "The heavens shall be rolled together as a scroll; and all their host shall fade away, as the leaf fadeth from off the vine, and as a fading leaf from the fig tree."

Like the ordinary observer of the present day, the ancient Jews conceived the visible stars to be more numerous than they really are, and references to the multitude of the stars and the host of heaven are very common. Though later writers clearly recognized the immensity of creation as compared with ordinary magnitudes, (as *e.g.*, Jer. xxxi., 37, "If heaven above can be measured, and the foundations of the earth searched out beneath, then will I also cast off all the seed of Israel"), yet the idea of building a tower to reach to heaven was treated quite seriously (Gen. xi., 1-6).

As might be expected, when men based their speculations on appearances rather than realities, differences of opinion as to the nature of phenomena were quite frequent. Indeed at the present day, when men of science build too high on too slender a foundation, wide differences of opinion are not unknown.

The author of Job had clearly connected rain with the clouds, "He bindeth up the waters in his thick clouds" (xxvi., 8), and in this he differs from other writers whose opinions were apparently more commonly current. It is true that in xxxviii., 22, 37, the "treasuries of the snow" and "treasuries of the hail" and the "bottles of heaven" are referred to, yet nowhere does he make mention of the "firmament," and it may well be that these are poetical expressions. If so, it is not unreasonable to assume that this writer as well as others had arrived at the conception that, like the rain, the phenomena of snow and hail were purely atmospheric.

References to the motions of the stars are not numerous. In Job xxxviii., 32, we find

> "Canst thou lead forth the Mazzaroth in their season?
> Or canst thou guide the Bear with her train?"

and in that early specimen of Hebrew poetry, the Song of Deborah, (Judges v., 20), with a fine flight of fancy the author triumphantly exclaims, "The stars in their courses fought against Sisera." This cannot well have anything to do with astrology as there are no references whatever in the Bible to astrology or astrologers until after the unfortunate acquaintance of the Children of Israel with the great Babylon, and then only in connection with Babylonian matters. The numerous references in Daniel are of this class, and also the following in Isaiah xlvii., 13, "Let now the astrologers, the stargazers, the monthly prognosticators, stand up, and save thee from the things that shall come upon thee."*

* Such individuals as are here referred to are not entirely extinct at the present time.

So I think the fighting of the "stars in their courses" is a poetical metaphor, used with the same idea of dramatic effect which animates a modern writer, when he says, speaking of his hero, "The very elements conspired against him."

We have another example of poetic license in Joshua x., 12, 13. The writer, quoting from the old "Book of the Just," says,

> "Sun, stand thou still upon Gibeon;
> And thou, Moon, in the valley of Aijalon,
> And the sun stood still and the moon stayed,
> Until the nation had avenged themselves of their enemies."

This is properly written as poetry in the Revised Version. The poet, writing in a glow of patriotic fervor of an event of national importance, has used a figure of speech which graphically expresses the completeness of a victory where the cause of the vanquished was hopeless "for the Lord fought for Israel."

The so called dial of Ahaz, has been the subject of much learned enquiry. "And Isaiah the prophet cried unto the Lord: and he brought the shadow ten steps backward, by which it had gone down on the dial of Ahaz" (2 Kings xx., 11). It is important to notice here that the same word in the original has in this passage been translated both "steps" and "dial"; so if we read "steps" for "dial" in the second place we probably get nearer to the meaning of the original "He brought the shadow ten steps backward on the steps (or staircase) of Ahaz."

Schiaparelli reasons from this, and probably rightly, that the dial of Ahaz was a grand flight of steps on which a shadow was cast from some other part of the building. The date of the retrogression of the shadow was about 700 B.C. and as the earliest dial with which we are acquainted, that of Berosus of Babylon, only dates back to about 390 B.C., it is most probable that the dial of Ahaz was in no sense a mathematical dial capable of accurately showing the passing of the hours. From the earliest days it could not escape attention that cast shadows would roughly indicate the time of day, and a grand staircase

up which the shadow from a building would creep from morning to noon, and down from noon till evening, would make a very fair dial of a rough sort.

The retrogression of the shadow "ten steps" may have been an effect due to refraction of the apparent disk of the sun, for it is, perhaps, needless to say that there is no astronomical evidence of any such extraordinary phenomenon as the backward motion of the earth or the actual displacement of the sun.

The Jews were always so much impressed by the wonders of nature that we would naturally expect some references to eclipses of the Sun and Moon, if such were visible in Palestine. Total eclipses of the moon are common enough anywhere, and it also happens that in 831 B.C. the sun was totally eclipsed at noon in southern Palestine. Thus it is not surprising to read in the book of Amos, (viii., 9), who lived about this time, "It shall come to pass in that day that I will cause the sun to go down at noon, and I will darken the earth in the clear day." Joel too, who was a little earlier than Amos says, (ii., 31), "The sun shall be turned into darkness, and the moon into blood before the great and terrible day of the Lord come." How well the language of these prophets expresses the scenic effect of eclipses will be recognized by all who are acquainted with these phenomena.

The greater planets, or "wandering ones," are so clearly distinguishable from the stars that it is remarkable that there are so few passages in scripture which unmistakably refer to these splendid orbs. Two at most can be traced, and these not without difficulty. In Amos v., 26, we read, "Yea, ye have borne Siccuth your king and Chiun your images, the star of your god, which ye made to yourselves." Now, according to Schiaparelli, *Chiun* (or *Kiyun*) should read *Kaivan*, which was the name of Saturn among the ancient Arabs, Syrians and Assyrians; and as we know that the Jews frequently lapsed into idolatry and star worship, it is not surprising to find them reproved by Amos for worshiping Saturn, a noticeable planet next in brightness to Jupiter.

Venus is the only other planet of which there is any record. "How art thou fallen from heaven, O ! day star, son of the morning !" exclaims Isaiah. The language is used figuratively of the King of Babylon, and, the better to picture his disastrous downfall, he is likened to the glorious planet which rules the morning sky. Yet, as it were, from the heights of heaven he is to be brought down to sheol, to the uttermost parts of the pit. (Isa. xiv., 15).

Another reference to Venus is thought to be found in the verse quoted above, "Canst thou lead forth the Mazzaroth in their season?", or, as the Authorized Version has it, "in his season." Some authorities hold that the *mazzaroth* were the constellations of the zodiac, but 2 Kings xxiii., 5, puts this contention out of court "He put down . . . . . them also that burned incense unto Baal, to the sun, and to the moon, and to the planets (the *mazzaloth*) and to all the host of heaven."

The *mazzaroth* or *mazzaloth* were evidently the object of worship, and we know that the constellations of the zodiac were hardly known among the nations from whom the Jews borrowed their star worship and much less were they worshipped as divinities.

We do find however that Venus, next to the Sun and Moon, was an object of worship among the Babylonians under the name *Istar*. The passage from 2 Kings I have just quoted places *mazzaroth* next after the Sun and Moon, and quite distinct from the rest of the host of heaven. How clearly the Babylonians recognized the superior brilliancy of Venus is poetically indicated in the following extract from an ancient inscription.

"Istar set up a glittering throne by the side of Anu the king, and plotted for the sovereignty of heaven."

According to Fox Talbot, *mazzaroth* is not improbably derived from *natsar*, meaning "watch" or "sentinel." No easily visible planet better deserves the name of sentinel of the Sun than Venus, for does she not follow him so closely that she

is known to us as Lucifer, the typical star of morning, or Hesperus, the queen of the evening skies?

The Babylonian Istar is characterized as Dilbat the announcer or herald of the Sun, for where *she* is seen the Sun is near at hand.

While the Jewish writers took much interest in the heavenly bodies, they were more concerned in using them "to point a moral or adorn a tale" than in grouping and naming the stars. Consequently we find in the whole Old Testament but five passages in which constellations or star-groups are mentioned. These are included in the accompanying table, in which is shown the various readings generally given, and also those which Schiaparelli, after special study, gives as most probably correct.

TEXTS OF OLD TESTAMENT REFERRING TO CONSTELLATIONS SHOWING DIFFERENT READINGS.

H.T., Original text as to names. *K.J.*, King James or Authorised Version.
R.V., Revised Version. *Sch.*, Schiaparelli's Reading.

Job ix., 9.

H.T. Which maketh Ash, Kesil and Kimah and Hadre theman.
K.J. Which maketh Arcturus, Orion and the Pleiades and the chambers of the South.
R.V. Which maketh the Bear, Orion and the Pleiades and the chambers of the South.
Sch. Which maketh the Hyades, Orion and the Pleiades and the Southern constellations between Canopus and Alpha Centauri.

Job xxxviii., 31.

H.T. Canst thou bind Kimah or loose the bands of Kesil.
K.J. Canst thou bind the sweet influences of Pleiades or loose the bands of Orion.
R.V. Canst thou bind the cluster of the Pleiades or loose the bands of Orion.
Sch. Canst thou bind the cluster of the Pleiades or loose the bands of Orion.

Job xxxviii., 32.

H.T. Canst thou lead forth the Mazzaroth in their season or canst thou guide Ayish with her children.
K.J. Canst thou lead forth Mazzaroth in his season or canst thou guide Arcturus with his sons.

R.V. Canst thou lead forth the Mazzaroth in their season or canst thou guide the Bear with her train.

Sch. Canst thou lead forth the Venus in her season or canst thou guide the Hyades (or Aldebaran and his train).

Job xxxvii., 9.

H.T. Out of the Heder cometh the tempest and cold out of the Mezarim.

K.J. Out of the Chambers of the South cometh the storm and cold out of the North.

R.V. Out of the chamber of the South cometh the storm and cold out of the North.

Sch. Out of the Southern Constellations cometh the storm and cold out of the Great and Little Bear.

Amos v., 8.

H.T. Seek him that maketh Kimah and Kesil.

K.J. Seek him that maketh the Seven stars and Orion.

R.V. Seek him that maketh the Pleiades and Orion.

Sch. Seek him that maketh the Pleiades and Orion.

I would like to say a word as to the poetical side of my subject. The Jews were essentially sensuous by nature, that is they were keenly alive to the impressions of the senses. They were not philosophic and were almost incapable of abstract ideas. They were not scientific nor logical, consequently their recorded impressions of nature are a series of fragmentary snap shots, strung together without logical sequence. The lyric is the natural medium of expression of such a type of mind, and most Hebrew poetry is of this class, that is to say, their poetry is the expression of intense personal feelings and emotions, and nature is used as a means to aid in expressing these emotions. To them the grandeur, the wonder, the mystery of nature appealed most strongly, just as in their religion they emphasized the power, the greatness and the majesty of God. So also, as the religious motive was naturally uppermost in the minds of the writers, natural phenomena are generally used to assist in revealing the attributes of God, or the manner of his dealings with man. There are many passages which reveal this tendency to find in nature a temple of the Almighty. I shall quote only a few.

"The heavens declare the glory of God;
And the firmament sheweth his handywork,
Day unto day uttereth speech,
And night unto night sheweth knowledge."

Ps. xix., 1, 2.

To the glory and beneficence of the Sun they were fully alive. In Ps. lxxxiv., 11, we have "For the Lord God is a sun and a shield," a metaphor expressing the bounteous goodness of God and his character as "a very present help in time of trouble." On reading Job xxxi., 26, I fancied Lord Byron must have done the same. Job says,

"If I beheld the sun when it shined,
Or the moon walking in brightness."

a beautiful image of the serene progress of the silver moon from its rising behind the eastern hills to its setting in the waters of the Great Sea. Byron, in one of his Hebrew Melodies says

"She walks in beauty, like the night
Of cloudless climes and starry skies."

In the Song of Songs vi., 10, is another splendid picture of majestic serenity,

"Who is she that looketh forth as the morning,
Fair as the moon,
Clear as the sun,
Terrible as an army with banners?"

I might cite image after image did time permit, but one more must suffice. All are familiar with the apostrophe to night and music in the Merchant of Venice,

"Soft stillness and the night
Become the touches of sweet harmony,
Sit, Jessica. Look how the floor of heaven
Is thick inlaid with patines of bright gold:
There's not the smallest orb which thou behold'st
But in his motion like an angel sings,
Still quiring to the young-eyed cherubins."

(Act v., sc. 1, 56-62.)

Shakespeare, I doubt not, had in mind the language of Job xxxviii., 7,

"When the morning stars sang together,
And all the sons of God shouted for joy."

It is a beautiful poetical image, and I have often thought it is more than that. All musical sounds are caused by waves or pulsations. If the pulsations are too rapid our ears do not respond. If they are too slow we may feel but cannot hear. *We* have our limitations; but an Infinite Being is marred by none of our imperfections. To the ear of God the slow pulsations of the planets and the stars in their orbits may make a music more beautiful than we can imagine. If Kipling's old Scotch engineer could find music in the rhythm of his man-made engines, it is not, I think, making God too much like a man to imagine the marvelous mechanism of the universe, the work of his own hand, as making supernal music in His ear.

TIDES OF LAKE HURON.

By W. J. Loudon.

DURING the summer of 1906 the observations on the tides of Lake Huron, which were begun the previous year at High Rock, Georgian Bay, were continued. The apparatus used was that described in a former paper, (*Trans. R.A.S.C.* 1905, p. 131).

Although some results were obtained, showing the presence of true lunar tides on the lake, yet the weather was very variable and the periods of calm, so necessary for good observations, were generally of short duration and often preceded or followed by sudden storms.

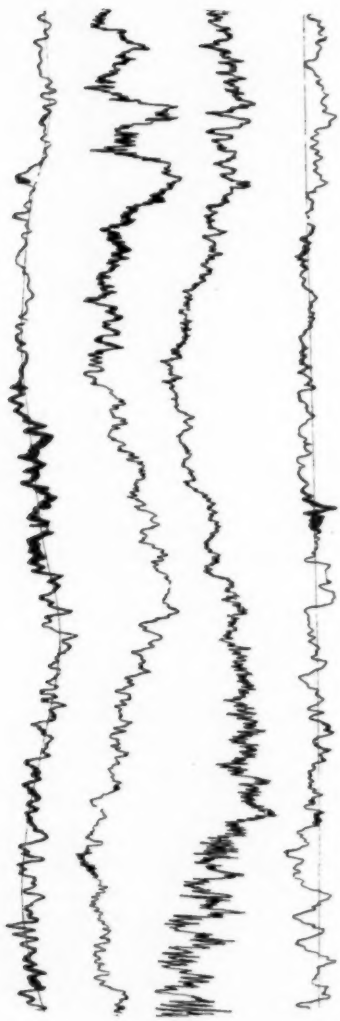
As a consequence of this, the records do not extend over long periods: in fact, some of the tidal curves represent intervals of not more than half a day.

Tracings, extending over a period of three days were not obtained, so that no calculation could be made of the times of lagging.

The following curves are presented, however, as they add a little to the general stock of information already possessed concerning the tides of Lake Huron.

Fig. 1 shows the tide of July 12. As there was a full moon on July 5, it is approaching a minimum value, which probably occurred on July 16-17.

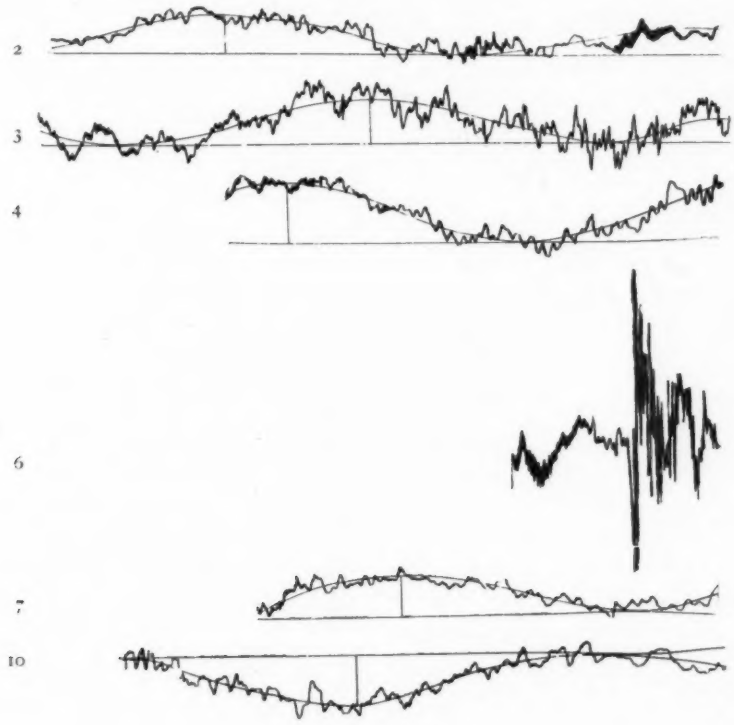
The curve is slightly irregular, and for that reason the rise or fall of the water could not be accurately measured. An estimate of its value gives three-quarters of an inch for the total (from high water to low): which would mean a minimum tide of about three-eights of an inch. This estimate may be too small by an eighth of an inch, so that it is probable the minimum tide lies somewhere in value between three-eights and one-half an inch.



Tidal Records, Georgian Bay. Figures 1, 5, 8, 9.

Curves One-Fourth Original Size.

In Fig. 2, which shows a portion of the tidal curve for the following day, July 13, more accuracy has been obtained. By drawing a horizontal tangent to the mean curve, a total displacement of seven-eights of an inch was found. This means a



Figurés 2, 3, 4, 6, 7, 10.
Curves One-Fourth Original Size.

tide of seven-sixteenths of an inch, which is doubtless not far from the truth.

Fig. 3 represents a portion of the tidal curve of July 21, the record starting from midnight of July 20. Although the curve is disturbed by *seiches* movements, the outline of the mean curve

is fairly regular. By drawing a horizontal tangent, it was found that the tide had increased in value to one and one-sixteenth of an inch, total displacement. This represents a rise or fall, measured from the mean level, of seventeen thirty-seconds of an inch. Such an increase was to be expected, as there was a new moon on July 21.

Fortunately, a calm spell ensued on July 25, and the resulting curve is shown in Fig. 4: it represents the tide four days after new moon. The total change of level was one and seven-sixteenths of an inch, so that the tide was twenty-three thirty-seconds of an inch above or below mean level. This was the greatest lunar tide noticed during the summer of 1906.

Fig. 5 exhibits the tidal curve of August 4, and shows how the water, which at first was calm, and gave every indication of good records, began to be affected latterly by an approaching storm, indicated by the large *seiches* movements.

As there was a full moon on August 4, if the weather had remained favourable, the second order of maximum tides might have been fully investigated; but, as shown in Fig. 6, the storm approached rapidly, and on the afternoon of August 5 suddenly appeared in the form of a thunder squall.

The curve of Fig. 6 is a continuation of that given in Fig. 5, and is interesting as it shows the sudden alteration of water level before and during the storm. This sudden squall destroyed the value of the records obtained for the following fifteen hours, as far as lunar tides were concerned.

The weather of August 6 and 7 was fairly calm, and on August 8, towards evening, there was every indication of a period of dead calm.

Figure 7 shows the curve for this interval, which lasted only ten or twelve hours, sufficiently long enough, however, to afford an opportunity of determining with some accuracy the secondary maximum after the period of full moon. By drawing the horizontal tangent, the total displacement was found to be one inch, so that the secondary tide, measured

from mean level, four days after full moon, is one-half of an inch.

Fig. 8 shows the effect of previous rough weather on the tidal curve of Aug. 14, which, however, is quite distinct in form, and shows a displacement from the mean level that might be estimated roughly at one-half of an inch.

Fig. 9 which exhibits the outline of the tidal curve for the next day, August 15, shows very little displacement from the mean level. This is remarkable, because the interval from noon of Aug. 15 until noon of Aug. 16 was one of dead calm, and had been preceded by a long interval of comparative calmness, as shown in Fig. 8.

The absence of tidal action on this particular day, especially under the most favourable circumstances (of dead calm preceded by comparative calmness) is difficult to explain.

When taken from the cylinder, the paper, on which the tracing had been made, showed a straight line, instead of the sinusoidal curve which indicates the tidal action : and, as every care and precaution had been taken to ensure perfect records, and the pulley and float had been working freely throughout the interval, it seemed as if the tidal action, which should have been rendered visible, had been counteracted by same influence which had produced an effect equal and opposite to that of the lunar tide.

Fig. 10 shows a portion of the tidal curve of September 19. As there was a new moon on Sep. 18, the tide is approaching its maximum value. The total displacement in this curve was one inch and a quarter, so that the tide was five-eights of an inch, measured from the mean level.

NOTES ON SOME DOUBLE STARS.

By T. E. Espin.

η Cassiopeiæ.—With the 17¼-inch Reflector the pair is very comfortably placed for measurement, and hence the agreement of the measures is unusually good. The colors of the stars are, *A* yellowish white, and *B* reddish purple. The following observations now have been made :—

Date	Position Angle	Distance	
1906·0794	233°·93	5″·64	
·0876	233 ·75	5 ·73	
·0904	233 ·80	[Clouded up]	
1906·086	233 ·8	5 ·685	Three nights
1907·0411	236 ·5	5 ·70	
·0465	236 ·3	5 ·65	
1907·044	236 ·4	5 ·675	Two nights

About 6½′ f lies a pair I discovered many years ago, and which I measured in 1892. It is mentioned in "*Celestial Objects.*" This season I have remeasured it with the following results :—

Date	Position Angle	Distance	Magnitudes
1907·0411	115°·0	4″·10	9·0, 9·0
·0465	114 ·6	4 ·25	
1907·044	114 ·8	4 ·17	Two nights

The previous measures in 1892 were :—

P = 112°·3 D = 4″·9

It is *B*D + 57°·171.

Those who have observed the glorious cluster *M.* 37 in *Auriga* will probably have noticed a strongly reddish orange star a little p and some 30′ south, of about 6½ mag. It is *B*D + 32°·1109, the place of which is

For 1900, $\alpha = 5^h\ 44^m\ 5{\cdot}5^s$, $\delta = +\ 32°\ 5'{\cdot}8$.

It is No. 57 of my catalogue of new red stars in *Monthly Notices*,

Note—f, following ; p, preceding ; n, north ; np, north preceding.

xlvi., p. 293, and No. 520 in Krüger's "Catalog der farbigen Sterne." Lately I have found that it has a minute *comes*, which I have measured as follows :—

Date	Position Angle	Distance	Magnitudes	
1907·0465	15°·8	14″·65	6·8, 13·0	
·1314	16 ·4	15 ·35	7·0 12·0	
1907·089	16 ·1	15 ·00	6·9 12·5	Two nights

The beautiful pair *ι Cancri* must have been observed many thousands of times with all sorts of telescopes, so that it is surprising that a neat little double in the same low-powered field should hitherto have escaped detection. It is the star *B*D + 29°·1821, whose place is

For 1900, $\alpha = 8^h\ 39^m\ 5{\cdot}2$, $\delta = +\ 29^\circ\ 33'{\cdot}0$,

and it is 47 sec. p and 15′ n of *ι Cancri*.

I have made the following measures of it :—

Date	Position Angle	Distance	Magnitudes	
1907·1752	72°·3	2·20	9·0 10·0	
·1917	72 ·6	2·80	9·0 10·5	
1907·183	72 ·4	2·50	9·0 10·2	Two nights

It is the most northern of the two brightest stars np *ι Cancri*.

Tow Law, Co. Durham, England.
March 18, 1907.

THE TELESCOPE.*

By D. B. Marsh.

THE telescope is undoubtedly the most important of all Astronomical instruments. It has given almost a new sense to the human race, whereby many of Nature's greatest mysteries have been revealed, and it is the instrument to which is attached the numerous recent devices, such as the camera and the spectroscope, which have so greatly aided in the study of celestial physics.

The exact date of the invention of the telescope and the inventor's name are not known. It was probably used in Northern Europe prior to 1609. In a casual way, Galileo learned of an instrument constructed with a large double-convex lens in combination with a smaller double-concave lens, placed in a lead tube, and so arranged that far away objects were distinctly observed.

Though Galileo was unable to see one, he soon wrought out the principle and constructed a telescope which magnified three times. This was shortly superseded by one magnifying eight times and so encouraged was he by this instrument that he soon constructed one magnifying thirty times. This was a great success, and many discoveries were made by it,—lunar mountains were seen for the first time, spots on the sun were observed, the planet Venus was shown to have phases similar to our Moon; Jupiter was found to have moons, and Saturn to have strange appendages, and the Milky Way was shown to be composed of myriads of stars.

The Galilean telescope was a wonderful instrument in its day, but it was soon to be surpassed. In 1637 Kepler suggested a telescope with two convex lenses in combination. The larger lens, as in Galileo's telescope, was placed toward the object to

* Abstract of the address of the president at inaugural meeting of the Peterborough Section.

be viewed, but the smaller lens, instead of being concave on both sides and placed inside the focus of the large lens, was a double-convex lens and was placed beyond the focus of the objective or large lens. This smaller lens was held near the eye, and was called the eye-piece.

After considerable experimenting, it was found that a comparatively small objective, with a long focus, was the most satisfactory. In 1672, Campani, of Bologna, constructed an instrument of this kind 136 feet long. Huygens made one 123 feet long, which he presented to the Royal Society of London, while Auzout had one constructed 600 feet in length, but it was too unwieldy. These telescopes, notwithstanding their great length, were far from perfect, as they were affected by both chromatic and spherical aberration. Newton believed it impossible to correct the chromatic defect, and in deference to the great philosopher's judgment, no one for some time seriously attempted the task. However, in 1758, an English optician named Dollond proved Newton wrong. On carefully examining various kinds of glass, he observed that some specimens had greater dispersive power, and it occurred to him to make a telescope objective combining two different kinds of glass. He found that by combining a convex lens of Crown glass, which has the least dispersive power, with a concave lens of flint glass an image could be formed with almost no chromatic defect.

This was another great step in the construction of telescopes, for with a 3-inch objective and a focus of only 45 inches, a magnifying power of 200 could be had. It is interesting to note that, owing to the difficulty of procuring optical glass, Dollond never constructed a telescope larger than 4 inches in diameter.

Between 1830 and 1860 the manufacture of optical glass was much improved, and lenses were made as large as 12 and 14 inches in diameter. In 1861, one 18 inches in diameter was made for the Dearborn Observatory at Evanston, Illinois. In 1871, this was surpassed by one of 26 inches aperture made for the U.S. Naval Observatory at Washington, D.C. These splen-

did objectives were made by Alvin Clark, of Cambridgeport, Mass., whose firm indeed has constructed some of the largest in the world—that of the Lick telescope, 36 inches in diameter, and the Yerkes, 40 inches in diameter. The lens of the Lick telescope, in its cell, weighs about 700 lbs. and cost $53,000. The focal length is 56 feet. The Yerkes objective weighs half a ton and cost $65,000.

So far I have been speaking of refracting telescopes only. Let me ask your attention briefly to reflecting telescopes. These are of three kinds—the Gregorian, the Cassegrainian, and the Newtonian. Philosophers believing it impossible to overcome the unequal refrangibility of the different colored rays of light, gave up the idea of perfecting the refracting telescope, and directed their attention to constructing an instrument on a different principle, using a concave mirror to form the image of the object observed. Mersenne, in 1639, suggested the employment of a spherical mirror, but the idea appears to have been dropped. Quite independently Gregory, in 1663, proposed a similar arrangement, using however a parabolic in place of a spherical mirror. He endeavored to find a workman able to construct such, but could not at that time.

In the Gregorian instruments the parabolic reflector is placed at the lower end of the tube, while on its axis and a short distance beyond its focus, is placed a small concave reflector. The light from the distant object falls upon the large mirror, from which it is reflected back to the small one, which throws it back through a hole in the centre of the large reflector. It then passes into the eyepiece, which, indeed in Gregory's time had been much improved by Huygens.

Gregory's efforts along this line, turned Newton's attention to reflecting telescopes, and he set to work experimenting on an alloy suitable for a speculum. In 1669, he cast his first disc and began to grind it, but it was not until 1672 that he had real success. Then he made two small instruments, one of which was only about an inch in diameter, with a magnifying power of about 38.

The principle of Newton's telescope, differed from Gregory's in that it had a small plane mirror placed in the cone of light from the reflector, at an angle of 45 degrees. Being placed inside the focus, this mirror turned the light cone at right angles to its original direction, thus forming the image outside the tube, and obviating the necessity of a hole in the parabolic reflector.

About the same time that Newton completed his instrument, the Cassegrain construction was proposed. This was the same as the Gregorian telescope except for the small mirror. In the Gregorian this mirror was concave, while Cassegrain proposed a convex mirror, to be placed inside the focus. It brings the light from the object to a focus through a hole in the center of the large parabolic mirror.

The largest Cassegrainian telescope in use to-day is in the Melbourne Observatory, erected in 1870. It has an aperature of four feet, and is used in observing and photographing the nebulæ and star-clusters in the southern hemisphere.

Owing to the difficulty in obtaining a suitable alloy, little progress was made for some time in constructing reflecting telescopes. In 1718, however, Hadley, the inventor of the sextant, constructed one on the Newtonian principle, 5 feet in length. This instrument magnified over 200 times, and it revealed as much as the old refracting telescopes. Perfect as this Newtonian telescope seemed to be, the Gregorian type held the field until 1774.

By using a small Gregorian telescope, Herschel had his attention directed to the wonders of Astronomy, but his income being too limited to purchase an instrument he set about making one for himself. During his life, he is said to have made upwards of 400 telescopes, mostly of the Newtonian type. Among his earliest efforts was the construction of a 5-foot reflector which was a grand success. Then came one 7 feet in length. The largest of his instruments was completed under George III. in 1789. This telescope surpassed all previous efforts, as it was actually 40 feet long, and had a reflecting mirror 4 feet in diameter. The story of Herschel's work with this great telescope would fill a volume.

One of the best specimens of the Newtonian reflector was produced by Mr. Lassell, of Liverpool, England. With it two satellites of Uranus, a satellite of Saturn, and the single satellite of Neptune were discovered. This instrument is now in the Royal Observatory of Greenwich.

The largest telescope of the reflecting type was constructed by Lord Rosse, an Irish peer. It has a diameter of 6 feet, but it can be used only for observations on or near the meridian. At the present time both refracting and reflecting telescopes are in use, and are brought to a great degree of perfection. Just which is better, it would be hard to say. It depends largely on the requirements of the observer. The old speculum metal reflector has been almost discarded, and glass, coated with silver, has been substituted. The glass is much superior to the metal, as it can be figured more accurately, and if tarnished the silver can be renewed without changing the figure of the mirror.

For observing nebulæ and star clusters, perhaps the reflecting telescope is to be preferred, providing the mountings are suitable. The silvered mirror can be made to reflect 90 per cent. of the light it receives. The refracting telescope is much more convenient to manipulate, and requires much less attention. The lenses are so perfectly made that the chromatic and spherical aberrations are reduced to a minimum, so far as visual observation is concerned. For photographic purposes, an extra lens is sometimes placed before the visual objective, which suitably corrects for the rays effective in photography. This is done on the 36-inch Lick, and the 40-inch Yerkes. In some cases the light passes through colored screens which allow to pass only those rays for which the telescope is corrected. Taylor, of the firm of Cooke & Sons, has devised a 'triple' objective, which, it is claimed, is suitable for both visual and photographic work without the use of screens.

Lastly, let me refer to the horizontal telescope. In this case the telescope is rigidly fixed along the ground and the light from the heavenly body is reflected into it by a perfectly plane mirror moved by clockwork.

AUDIBILITY OF THE AURORA.

By W. F. King.

AT the meeting of the Ottawa Section, R.A.S.C., on May 9th, during the discussion which followed the reading of Mr. McDiarmid's paper on the Aurora reference was made to the sounds, which, it is affirmed, have been occasionally heard, proceeding from brilliant auroræ.

Doubt has been cast upon the reality of this phenomenon from the fact that apparently the sound has never been heard by any of the scientific Arctic explorers, though they have listened for it. The evidence of those who claim to have heard it is commonly, in scientific writings, turned by the supposition that the sounds are due, not to the auroral movement, but to the cracking of ice, the driving of snow before the wind, etc.

In this connection may be cited a piece of evidence which, though in print for nearly twenty years, has not yet found its way into the literature of the subject.

Mr. Wm. Ogilvie, the well-known surveyor and explorer of Yukon Territory, in a report forming part 8 of the Report of the Department of the Interior for the year 1889, says :—

"As to the aurora making an audible sound, although I often listened when there was a very brilliant display, and despite the profound stillness which is favorable to hearing the sound, if any sound occurs. I cannot say that I ever even fancied I heard anything. I have often met people who said they could hear a slight rustling sound whenever the aurora made a sudden rush. One man, a member of my party in 1882, was so positive of this that, on the 18th November, when there was an unusually brilliant and extensive display, I took him beyond all noise of the camp, blindfolded him, and told him to let me know when he heard anything, while I watched the play of the streamers. At nearly every brilliant rush of the auroral light

he exclaimed : ' Don't you hear it ?' All the time I was unconscious of any sensation of sound."

The simple test applied disposes of two explanations which may suggest themselves in ordinary cases—conscious imposture, and self-deceit from the impression on the mind produced by the seemingly violent movements of the streamers. That the sensation of sound coincided with the rush of the streamers shows that what was heard was not the wind, unless this wind was a phenomenon of the aurora. There remains the curious fact that the sound was not heard by both. Whether this was due to difference as to keenness of hearing, or to some physiological effect to which different persons are not equally sensitive does not appear.

It is interesting to note that at the reading of Mr. McDiarmid's paper there were present four persons, members of a prominent Ottawa family, who have heard the sound of the aurora.

It was in Gaspé some years ago, in the month of August. The aurora was a very brilliant one, forming a corona overhead with diverging streamers covering almost the entire sky. The movements of the streamers were very rapid, and accompanied by a sound, described as of a hissing or whizzing sound, and very distinct. The sound recurred at every brilliant flash for more than an hour, and was heard by all the members of the family (six). The night was perfectly calm, and the place far enough from the sea to preclude the supposition that the sound could be confounded with that of the waves, to which indeed it had little resemblance.

MEETINGS OF THE SOCIETY

AT TORONTO.

April 2.—The meeting this evening, by courtesy of the University authorities, was held in the Chemical Building of the University. The Honorable W. Mortimer Clark, Lieutenant-Governor of Ontario, was chairman, and a representative audience filled the room.

Prof. E. Rutherford, D.Sc., F.R.S., delivered a very interesting address on "Some Cosmical Aspects of Radioactivity," illustrating it by experiments and lantern slides. A full report of the address will be found on page 145.

A hearty vote of thanks was moved by Mr. John A. Paterson, K.C., and seconded by Professor Baker. Reference was made to the great achievements of the lecturer at McGill University, and to the fact that the success of a university does not depend so much upon its board of governors, its senate or its councils, but rather upon the ability and character of its professors. The chairman, on presenting the vote of thanks expressed the hope that Professor Rutherford might long be spared to continue splendid work in his new position as professor of physics in the University of Manchester.

April 16.—The following were elected to membership:

Harry P. Mills, Toronto;
Prof. William H. Day, B.A., Guelph;
P. E. Clarkson, D.D.S., Toronto;
Miss Bessie Ross, Toronto;
Robert Tyson, Toronto;
Miss M. Woolley, Toronto;
Thomas S. Plaskett, Toronto;
Mrs. H. S. Saunders, Toronto;
E. Pugsley, B.A., Port Rowan;
Stewart Buck, B.A., Port Rowan;
Miss I. A. Templeton-Armstrong, Port Rowan.

Mr. L. Gilchrist, M.A., spoke on "Applications of the Interferometer in Spectroscopy." After explaining the nature of light and the phenomenon of interference, the interference instruments of Michelson and Fabry and Perot were exhibited, the fringes being produced by sodium light. The determination of the length of the metre in wave-lengths was described and the use of 'visibility fringes' in analysing spectral lines was illustrated.

April 30.—Mr. J. Frederick Sharpe, gave a paper on "A few Facts about the Great Pyramid." Quoting from various authorities on the subject, Mr. Sharpe showed that the shape and dimensions of the Great Pyramid appeared to exhibit on the part of its architect, a knowledge of various astronomical and cosmical facts, (such as the length of the day and of the solar year, the size and configuration of the earth, its distance from the Sun, etc.,) quite as accurate as that possessed by scientists of the present day. Its mechanical and architectural excellence was equal, if not superior, to anything of modern times. These facts were taken by many thinkers of the day to indicate that the Pyramid was planned and built under Divine inspiration, allusions in the Scripture, both the old and the new testaments tending to bear out this theory.

An interesting discussion followed, in which it was suggested that the time of the construction of the Pyramid as determined by the orientation of the 'Grand Gallery' with respect to certain bright stars was not simply 5000 years ago but a 'precession' cycle added to this, or 30,000 years ago. Mr. Sharpe was asked to continue the subject at a later date.

May 14.—The following new members were elected :

E. B. Waite, Chicago, Ill.;

Prof. J. Matheson, Queen's Coll., Kingston ;

Prof. N. F. Dupuis, M.A., F.R.S.C., Queen's Coll., Kingston ;

George W. Robertson, University of Toronto, Toronto.

Reference was made by the President to the recent death of Mr. James Todhunter, for many years an active member of the Society, and the donor of one of its telescopes.

Mr. A. F. Miller, on behalf of Mr. Joseph Townsend, of Dixie, presented to the Society a very beautiful specimen of meteoric iron. Several years ago Mr. Townsend gave the Society a fragment broken off the same specimen. Mr. Miller had learned that the meteorite was kept for years in a collection of curios owned by the late Mr. Edward Terry, of Toronto.

The paper of the evening was by Mr. David Howell, and dealt with "Recent Applications of Photography to Astronomy." Mr. Howell made reference to some early meetings of the Society, and several slides of photographs made in those days were shown. They served to emphasize the progress made by the Society.

The development of photographic lenses to almost meet theoretical requirements has removed many disadvantages formerly felt. Many other difficulties had been overcome by the introduction and improvement of color sensitizing dyes whereby gelatine dry plates can now be obtained that are fairly evenly sensitive to the whole visible spectrum. A number of these dyes were mentioned and their optical characteristics given and illustrated on the screen by photographs of the spectrum obtained on plates prepared with them. Improvement has also been made in the preparation of the plates whereby a somewhat finer grain is possible. Special dyes for color filters have been introduced, whereby the part of light not required could be cut off without increasing the exposure to the same extent as had been necessary up to very recently.

A detailed description of filter 'Yellow K,' one of the latest of these, was given, with a series of comparison spectrograms made under varying conditions. In comparison with the older dyes, this shows great improvement in this yellow dye for its special purpose.

These improvements have been quickly utilized in astronomy. In photographing stellar spectra, the solar corona and

other eclipse phenomena, and in obtaining more correct photographs than had hitherto been possible.

A description of the spectro-heliograph was given, and a number of the photographs taken with it were shown on the screen.

A description of the photographing of Mars at Flagstaff Observatory was also given, whereby results were obtained which confirmed some of the detail shown on the drawings by Percival Lowell and others. These photographs were projected on the screen with the drawings, for comparison.

May 28.—The following were elected members:

Prof. Wm. Findlay, Ph.D., McMaster Univ., Toronto.
Dr. Thos. H. Whitelaw, B.A., Edmonton, Alta.
W. A. Eastman, Grand Rapids, Mich.
W. E. Groves, Toronto.

Dr. W. Bell Dawson, F.R.S.C., of Ottawa, Engineer in charge of the Tidal Survey of Canada, gave a paper on "Variations in the Leading Features of the Tide in Different Regions." By means of a map and diagrams it was explained how the Tidal Survey carried on its work, and the peculiar types of tides in different regions were described. A full account of the paper will be given in a later issue of the JOURNAL.

The discussion which followed showed a great interest in the subject.

PROGRAMME FOR APRIL-JUNE, 1907.

April 2,	Some Cosmical Aspects of Radioactivity. Professor E. Rutherford, F.R.S.
April 16,	Applications of the Interferometer in Spectroscopy. L. Gilchrist, M.A.
April 30,	A few facts about the Great Pyramid. J. Frederick Sharpe.
May 14,	Recent Applications of Photography to Astronomy. David J. Howell.
May 28,	Variations in the Leading Features of the Tide in Different Regions. W. Bell Dawson, D.Sc., F.R.S.C., Ottawa.
June 11,	Critical Temperatures in Relation to Cosmic Theories. R. S. Dewar.
June 18,	Open Air Meeting on Observatory Lawn.

E. A. D.

AT OTTAWA.

March 28.—Mr. C. A. Bigger opened his paper on "The Geodetic Survey of Canada" with a historical sketch of the development of geodetic surveys in various countries. At first the primary object was to obtain the length of an arc on the earth's surface, to determine its form and figure. Later, this was extended into a general primary survey obtaining the accurate positions of a number of stations, these forming the basis from which secondary stations and surveys down to the minutest details could finally be obtained. In the principal European countries, in India, and in the United States a primary survey is either completed or well under way, while in Canada only a beginning has been made.

After referring to the reasons for this delay, the lecturer spoke about the inception of the work in Canada by Dr. King and himself, and told of what had been done in the way of erecting observing towers. He described, illustrating by drawings, the towers already erected in Eastern Ontario, and on a map of Ontario and Quebec showed these stations, with others already selected as sites for such towers. Owing to the level and rolling nature of the country it is difficult to find suitable sites, and the towers require to be much higher than is required in a more hilly country, some having been erected 90 feet high. The paper closed with a brief discussion of some of the technical features of the work.

Dr. King gave a brief summary of the advantages to be gained by a Geodetic Survey of Canada; and Dr. Klotz pointed out how, especially in Ontario, the lack of properly co-ordinated primary stations resulted in very faulty maps.

April 11.—Mr. R. M. Stewart, in his paper on "How Standard Time is kept," began by explaining how time was measured, the fundamental unit being the sidereal day, from which the mean solar day, the standard in general use, is obtained. The two essential parts of a clock are the escapement and the pendulum.

The principal types of escapement with the advantages and disadvantages of each were described, and the lecturer then described the various forms of compensation pendulum, from the earliest gridiron type to the perfected mercury compensation and invar pendulums of the present day, the various forms being illustrated by lantern slides and diagrams. The various external conditions which affect the rate of even the best clocks were then dealt with and the very complete and perfect method employed here of keeping the pressure and temperature, the two variables having the greatest effect upon the rate, constant, were described. A description of the mean time standard with the method of effecting the small corrections required from the time room was followed by an explanation of how the secondary regulators in the Observatory and the Departmental and Parliament buildings were kept in step with the primary clock by a synchronization current flowing every two seconds. Each of these regulators in turn controlled electrically a number of dials in the various rooms whose hands moved once a minute.

The lecturer concluded by a short description of the method by which time is distributed to the public by means of a noon signal, by signals sent according to a pre-arranged scheme to the telegraph companies and also by telephone. The President, Dr. King, and Mr. Plaskett complimented Mr. Stewart on his work, the latter stating that the time service installed by Mr. Stewart, and especially that part relating to the control of temperature and pressure for the standard clock, was not equalled anywhere.

April 25.—Dr. King read an able and interesting paper on the "Theory of Least Squares."

He began by considering the elementary principles forming the basis of the method of least squares. The assumptions as to the nature of the errors which occur in measuring any quantities must be justified by the results, and justification for making arbitrary assumptions in least squares is given by the fact that it is the course followed in other branches of applied mathematics. The difficulty usually felt by students in proofs of the law of

error is due to a want of clearness of statement of the assumptions made as to the characteristics of the errors.

Dr. King next considered the definitions of some of the terms involved, such as *constant error*, *periodic error*, and *accidental error*. Accidental errors only are treated by the method of least squares. The postulate that positive and negative errors are equally likely to occur was discussed with some fullness, numerous examples being given.

Six methods of proving the law of error were discussed in the paper. The first, the one usually given in the text-books, is due to Gauss. The second is based on the principle of the arithmetic mean. The third depends on the assumption that each error of observation is made up of a great number of elementary infinitesimal errors. The fourth is based on the hypothesis of a large number of finite two-valued (positive and negative) elementary errors. The fifth, due to Professor Crofton, supposes the elementary errors to be of finite magnitude, though small, and capable of taking many values. The sixth form is due to Sir John Herschel. These proofs were critically examined, and a proof was given, developed by Dr. King himself, which showed how the proof for two-valued could be extended to many-valued elementary errors.

An interesting discussion followed, and the unanimous sentiment of the members present was that the paper was of exceptional value and should be published in complete form.

March 9.—Mr. R. M. Stewart read Mr. F. A. McDiarmid's paper on the "Aurora."

The paper began by a short description of Auroræ as seen by classical and other historical writers and then proceeded to a description of the two main classes into which the auroræ may be divided,—those which preserve their form and appearance a considerable time, and those which are changing incessantly. He showed how the two classes and the particular forms of each class merge into each other and form a continuous series, illustrating his remarks by some fine slides showing many auroral effects.

A connection between the height of the aurora and the area over which it is visible was developed. Low auroræ such as those west of the sun in polar regions are almost invariably local while the wide-spread displays usually seen in lower latitudes are at a comparatively great height. A connection was also shown between auroræ and variations in terrestial magnetism, as well as the coincidence of the auroral period with the sun spot curve.

It was shown from the evidence of the polariscope and spectroscope, that auroral light was the product of luminous gases and was presumably due to the electrical discharges in the rarefied upper air.

Edlund's theory depends on the phenomena of unipolar induction; assuming the earth to be a magnet its rotation creates an electric field, under whose influence electrified molecules are drawn from the equator towards the poles through the rarefied upper air, and the discharge takes place in high latitudes. Unterweger supposes that the potential necessary for the discharge arises from the compression of the cosmic ether in front of the earth in its voyage through space in company with the Sun, thus explaining the duirnal and annual periods.

May 23.—The last address of the winter-spring programme was by Dr. Otto Klotz, on the "Seismograph." The speaker explained the requirements of an ideal seismograph. The desideratum aimed at is a "steady-point" which shall impartially record the pulsations passing through the earth. The pendulum, governed by the force of gravity, answers best. Particular attention was drawn to the effect upon the time of oscillation, of the inclination of the axis of rotation, the object being to increase the period, in which case the pendulum will not itself be so readily set vibrating by a disturbance imparted to the pier on which it rests.

The Ewing-Milne, Milne and Omori pendulums were criticised and a detailed description of the Bosch instrument installed at the Dominion Observatory was given. In it there are two pendulums, one mounted E-W, the other N-S, and the

record is made photographically. This instrument records a motion of the earth of $\frac{1}{30,000}$ inch. Though mounted on a cement cube of more than a yard, and wholly disconnected from the cement floor, yet a person approaching the pier gives the instrument a sufficient "tilt" to be distinctly shown.

Dr. Klotz then gave a summary of our knowledge of earthquake waves, with illustrations. Some recent earthquakes were described, and a statement was given of work now under way at the Observatory. This is referred to more fully in the "Notes from the Dominion Observatory" in this issue.

Since the last issue of the JOURNAL the following new members have been elected.

James Campbell Weir, 33 Nazareth St., Montreal.
James L. Weir, 227 Nepean St., Ottawa.

J. S. P.

AT PETERBOROUGH.

Organization.—Following a lecture given by Rev. Dr. Marsh, of Springville, under the auspices of the Young Men's Guild, in Charlotte St. Methodist Church on February 26, a meeting of those interested in astronomical study was called for the purpose of discussing the advisability of forming a local section of the Royal Astronomical Society of Canada. Mayor R. F. McWilliams, B.A., occupied the chair, and after Dr. Marsh had outlined the object and work of the Society it was decided to proceed to organize a section. A committee, consisting of Dr. Marsh (president), Dr. F. C. Neal (secretary), Mayor McWilliams, D. E. Eason, S. W. Lowry, Dr. McFall, Rev. H. M. Manning and Rev. J. G. Potter, was appointed to draw up a constitution. The committee met on March 9, and adopted the constitution of the Ottawa Section. The following officers were elected :—

President, Rev. D. B. Marsh, Sc.D.
1st Vice President, William Pringle.
2nd Vice President, Duncan Walker, B.A.
Treasurer, D. E. Eason, B.A.Sc.
Secretary, F. C. Neal, B.A., M.D., 298 King St.
Councillors, S. W. Lowry, W. A. McFall, M.D., F.T.C.M.

March 22.—A lecture was given by Dr. Marsh on the planet Neptune.

April 5.—The formal inaugural meeting of the Section was held in the Y.M.C.A. lecture room, Mr. Richard Lees, B.A., being in the chair. The president's address was on ' The Telescope," an abstract of which is given on page 188.

April 19.—The president addressed the meeting on " Solar Physics." The dimensions, distance and motions of the Sun were explained and an account given of the various solar phenomena—sun-spots, faculæ, prominences and corona. The lecture was illustrated by numerous lantern slides.

May 3.—At the request of the Council of the Society, the president, Dr. C. A. Chant, went to Peterborough to address the Section and assist in organization. The meeting was in the Y.M.C.A. hall which was crowded. The subject of the lecture was " Exploring the Sun's Atmosphere." After explaining the general structure of the Sun and the teachings of the spectroscope a detailed account of the investigations made by Hale with the spectroheliograph was given. In conclusion reference was made to the strenuous efforts now in progress to correlate the solar and terrestrial cycles and thus secure means for long-distance forecasting.

May 17.—The lecture for the evening was given by Rev. Dr. Marsh on " The Extent of the Universe." It consisted of a sketch of the various features of the heavens, the distances apart being illustrated by the time required to traverse them by an express train, a cannon ball and by light.

Much interest and enthusiasm have been aroused by the formation of the Section. At the next meeting the subject of discussion will be " Earthquakes," and papers will be given by several members.

The membership is 47. A full list of all members of the Society will be included in the next issue of the " Astronomical Handbook."

NOTES FROM THE DOMINION OBSERVATORY.

Astrophysics.—The new spectrograph is now in regular use and gives star spectra of fine quality for measurement. It is very convenient in operation and the guiding mechanism works to perfection. It has been tried both with single prism and the train of three prisms, and the exposure-time required in each case, considering linear dispersion, compares very favorably with the old instrument. This is probably in part due to the more accurate guiding possible, and also to the better proportion of the optical parts, and the transparency of the single material camera lens. As previously mentioned in these Notes, this objective gives an exceedingly flat field when used with a single prism, extending over the whole range of visible spectrum and to as far in the ultra-violet as the prism will transmit. Evidently therefore the whole star spectrum which can be obtained in a single exposure can be accurately measured, a decided advantage in early type stars with few lines. The same objective with three prisms does not, however, give so good a field, although still of greater extent than that given by the regular cemented triplet.

The outside temperature box constructed of aluminum and lined with felt is kept at constant temperature by a pair of electric contact thermometers which respond to changes of temperature of 0·1° C. Thus, the inside of the prism box and consequently to a still greater extent the glass of the prisms, must remain at almost absolutely constant temperature.

Flexure, which was the source of much trouble in the old instrument, is entirely overcome in the new spectrograph so far as exposures of two hours' duration are concerned. Moreover the careful arrangement and adjustment of the comparison light, and the accurate means of focusing the camera employed, together with the removal of the two previously mentioned sources of error, should ensure complete freedom from syste-

matic displacements of the lines, and give trustworthy results. Only two or three plates have as yet been measured but they entirely substantiate the above remarks.

All the spectra obtained of the spectroscopic binary ι Orionis, which was under observation here last winter have been reduced, and the results applied to a determination of the elements of the orbit. Owing, however, to the very diffuse nature of the lines and to the fact that on most of the plates only two lines are measurable, the measures are probably subject to a considerable correction, and in consequence there has been some difficulty in obtaining a satisfactory curve. The orbit has an eccentricity of about 0·75, which is the greatest yet determined for any spectroscopic binary. It is not probable that the elements can be determined very exactly, and it seems advisable to wait for further observations to fill gaps in the present curve before completing the work. The period determined here, with which the early observations of Frost and Adams accord, is 29·12 days.

Mr. N. B. McLean, B.A., Fellow in Mathematics at the University of Toronto, has recently joined the staff, and is engaged in measuring and reducing star spectra. It is hoped, thereby, to keep the measuring nearly up to the observing, its necessity especially in binary star work, having been repeatedly shown.

J. S. P.

The Seismograph.—Since the last notes the principal movement recorded by the Bosch photographic seismograph is the Mexican earthquake of Sunday, April 14th, last. From the seismogram it appears that the earth was in a state of unrest for hours previous to the rupture. Of the latter the preliminary tremors arrived at $6^h\ 15^m\ 6^s$, G.M.T., April 15. The second group arrived at $6^h\ 19^m\ 50^s$, G.M.T., for the E-W pendulum. Similarly for the N-S pendulum, preliminary tremors, $6^h\ 14^m\ 56^s$, G.M.T., second group, $6^h\ 19^m\ 34^s$, G.M.T., from which the approximate distance of 3700 km. to the epicentre follows, agreeing well with the actual distance to the epicentral area in

the state of Guerrero. The maximum amplitude 15 mm. was about one quarter of that for the San Francisco one. The quakes continued for over an hour and a half.

As a seismic disturbance it was far more severe than the one of Kingston in January last. The Mexican earthquake was reported to the local press by the Observatory as a severe and destructive one, although at the time the despatches from Mexico City were unaware of its intensity.

An attempt is being made here to establish the relationship between the change of the zero position of the horizontal pendulum of the seismograph with the change of the daily barometric gradients as taken from the daily Weather Charts; that is, the investigation seeks to determine whether the theoretical tilting of the pier towards the area of "high barometer" is shown by a deflection of the pendulums.

It is intended to carry on magnetic and gravity work during the present season over a considerable area of Canada to form part of a systematic scheme for the Dominion. For the former a fibre declinometer, dip circle and magnetometer will be used, and for the latter the half-seconds pendulum swung in an air-chamber under constant pressure.

The newer science seismology has shown a relationship between it and terrestrial magnetism and gravity, and their proper correlation is one of the interesting problems awaiting solution.

O. K.

Time Service.—In conformity with the decision to replace the key as an instrument for the observation of transits, by the travelling wire micrometer, the last of the portable transit instruments belonging to the Observatory is having a micrometer attached. The attachment is now being made in the Observatory workshop, and, while in the main similar to the others which are in use here, it will embody several alterations and improvements suggested by experience. While progress in the making of such an instrument is necessarily slow, it is hoped to

have it completed in a couple of months, in addition to some minor repairs to the instrument.

On account of the dismantling of the instrument for this purpose, as well as from some other causes connected with the exigencies of routine work, the research work in connection with transit observations has been practically discontinued for the present, but it will be resumed at the earliest opportunity. A more detailed description of the problem at issue than has yet appeared, will be given in the next number of the JOURNAL.

Mr. D. B. Nugent, B.A., late demonstrator in Physics in the University of Toronto, has recently been appointed to the Time Service staff, and his assistance will no doubt have a marked influence in increasing facilities for work in this and other directions.

R. M. S.

GENERAL NOTES.

June 10, 1907.—A telegram has been received at Harvard College Observatory from Mr. Zaccheus Daniel of the Princeton Observatory stating that an object suspected of being a comet, was observed by him June $9^d.804$ G.M.T. in

R. A. $23^h\ 48^m\ 33^s$.

Dec.—1° 8′.

The object was visible in a small telescope. "No motion observed."

June 12, 1907.—A later telegram has been received from Dr. W. R. Brooks stating that the comet announced above was confirmed by him on June 11.8 G.M.T. in the following position

R. A. $23^h\ 53^m\ 10^s$

Dec.—0° 40′

A Partial Eclipse of the Moon, July 24, 1907.—This will be visible in the United States and generally throughout North and South America, except in the northwestern part of North America. It will be partly visible in Europe and Africa. Commencing in Toronto at 8 58 p.m., ending at 1 46 a.m.

Sir Charles Todd, F.R.S., director of the Astronomical and Meteorological Observatory of South Australia, has retired, having reached the age of eighty years. He is succeeded by Mr. F. Griffith.

John Krom Rees, since 1881 professor of geodesy and astronomy and director of the Columbia College Observatory, died on March 9, aged 55 years. Professor Rees had been ill for several years.

The death is announced of Henry Chamberlain Russell, F.R.S., government astronomer of New South Wales since 1870, at the age of seventy-one.

SUMMARY REPORT OF THE WEATHER IN CANADA. APRIL, 1907.

METEOROLOGICAL OFFICE, TORONTO, JUNE 10, 1907.

TEMPERATURE. — The temperature was below the average in all portions of the Dominion, in striking contrast to April of last year when it was nearly everywhere much above the average. The most pronounced negative departures occurred in the Western Provinces, ranging from 6 to 13 degrees. In Ontario, also, it was below the average, being as much as from 7 to 11 degrees below in northern and from 4 to 6 degrees in southern localities.

The following are the highest and lowest temperatures recorded at various stations:—

British Columbia.—Dawson City, 60, - 30; Atlin, 56, - 3; Port Simpson, 60, 30; Victoria, 68, 32; New Westminster, 66, 31; Barkerville, 60, 10; Kamloops, 76, 29; Agassiz, 70, 31.

Western Provinces.—Edmonton, 64, 10; Battleford, 50, 2; Prince Albert, 46, 0; Calgary, 66, 6; Medicine Hat, 64, 14; Swift Current, 54, 8; Qu'Appelle, 44, - 2; Minnedosa, 52, - 5; Winnipeg, 54, 5.

Ontario.—Port Arthur, 53, 1; White River, 46, - 30; Southampton, 62, 12; Parry Sound, 60, 7; Port Stanley, 60, 13; Toronto, 70, 18; Kingston, 64, 17; Rockliffe, 60, 2; Ottawa, 68, 14; Uxbridge, 70, 13; Paris, 70, 16; Owen Sound, 63, 11; Peterboro', 70, 12; North Gower, 71, 15; Lakefield, 70, 15; Sutton West, 70, 12; Bancroft, 66, 10; Meaford, 60, 15; Clinton, 69, 12; Haliburton, 68, 5; Lucknow, 68, 11; Port Dover, 69, 15; Pt. Clark, 67, 18; Sarnia, 66, 16; Kenora, 48, 5; Copper Cliff, 56, 3; Huntsville, 65, 7; Bruce Mines, 55, 7; Orillia, 68, 12; Port Burwell, 66, 14; Hamilton, 73, 20; Brantford, 69, 15; Bloomfield, 68, 18; Stratford, 67, 12; Beatrice, 66, 6; Bala, 64, 11; Otonabee, 67, 16.

Quebec.—Montreal, 64, 13; Quebec, 63, 11; Father Point, 58, 8; Sherbrooke, 64, 12; Brome, 67, 11.

Maritime Provinces.—Charlottetown, 66, 12 ; Chatham, 66, 2 ; Sydney, 62, 12 ; Halifax, 68, 17 ; Yarmouth, 58, 20 ; St. John, 54, 13 ; Moncton, 67, 7 ; St. Stephen, 64, 7 ; Pt. Hastings, 67, 14 ; Summerside, 60, 9.

PRECIPITATION.—The precipitation in British Columbia did not differ much from the average, being slightly in excess of it in some districts and not quite equal to it in others. In the Western Provinces, at Calgary and in the immediate neighborhood it was more than twice the average amount. At Swift Current, also, the normal was slightly exceeded, otherwise nearly everywhere else a deficit occurred. In Ontario it was exceeded in the Georgian Bay region but only locally in other districts, many localities recording a negative departure. In Quebec and New Brunswick it was above the average from an amount varying between one-half to two inches, whereas in Nova Scotia and Prince Edward Island it was very generally below the average, Halifax recording a deficit of one inch. In Ontario the chief positive departures were Parry Sound and Montague, 2·10 inches ; Gravenhurst, 1·70 inches ; Midland, 1·51 inches ; and the most marked negative departures, Stony Creek, 1·40 inches ; Lakefield and Port Stanley, 1 inch.

MAY, 1907.

The mean temperature for May was below the average throughout Canada, except in British Columbia and the Yukon Territory, where small positive differences were recorded. The negative departures from average were especially large from Saskatchewan to New Ontario, ranging between 10° in the former Province, and 13° in the latter District. In Quebec, differences were from 2° to 7° and in the Maritime Provinces from 3° to 4°. An excess of from 2° to 4° occurred in British Columbia, and of 5° in the Yukon Territory.

The following are the highest and lowest temperatures recorded at various stations :—

Yukon Territory.—Dawson City, 80, 22.

British Columbia.—Atlin, 66, 26 ; Port Simpson, 68, 34 ;

Victoria, 76, 40 ; Vancouver, 75, 35 ; New Westminster, 80, 38 ; Ladner, 74, 31 ; Agassiz, 85, 40 ; Barkerville, 66, 24 ; Kamloops, 86, 35 ; Nelson, 82, 31.

Alberta, Saskatchewan and Manitoba.—Edmonton, 76, 18 ; Calgary, 74, 16 ; Medicine Hat, 74, 16 ; Battleford, 68, 10 ; Prince Albert, 68, 3 ; Swift Current, 75, 12 ; Qu'Appelle, 72, 8 ; Minnedosa, 66, 15 ; Winnipeg, 74, 11.

Ontario.—Port Arthur, 60, 16 ; White River, 64, 0 ; Bruce Mines, 64, 21 ; Copper Cliff, 66, 22 ; Cockburn Island, 60, 21 ; Lake Talon, 78, 4 ; Parry Sound, 83, 16 ; Huntsville, 79, 16 ; Beatrice, 81, 15 ; Owen Sound, 83, 18 ; Southampton, 79, 24 ; Clinton, 80, 23 ; Lucknow, 79, 21 ; Stratford, 78, 25 ; Port Stanley, 79, 24 ; Port Burwell, 72, 23 ; Port Dover, 77, 24 ; Paris, 84, 25 ; Stony Creek, 88, 26 ; Toronto, 76, 26 ; Sutton West, 81, 24 ; Uxbridge, 80, 21 ; Peterboro', 79, 25 ; Lakefield, 78, 25 ; Bancroft, 79, 19 ; Kingston, 69, 28 ; Rockliffe, 76, 14 ; Ottawa, 82, 21.

Quebec.—Montreal, 74, 28 ; Brome, 77, 22 ; Sherbrooke, 75, 26 ; Quebec, 66, 25 ; Father Point, 60, 25.

Maritime Provinces.—Chatham, 77, 27 ; St. John, 63, 32 ; Fredericton, 73, 30 ; St. Stephen, 76, 25 ; Yarmouth, 60, 32 ; Halifax, 68, 28 ; Sydney, 69, 26 ; Charlottetown, 66, 28.

PRECIPITATION.—There was an almost general deficiency in precipitation over the Dominion, the widest departures from average occurring in British Columbia, where in most districts the rainfall was less than one inch. In the Western Provinces the aggregate of rain and melted snow was very generally less than half the average, but some few stations in northern Alberta and north-eastern Saskatchewan recorded an average amount. In Ontario, it was only in Algoma and Nipissing and the Niagara Peninsula that a normal amount was recorded, other parts of the province, and also western Quebec shewing a deficiency of between 30 and 40 per cent. In eastern Quebec and the northern portions of the Maritime Provinces, including Prince Edward Island, it was slightly in excess, while other districts shewed a small deficiency.

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